NASA/LANGLEY 55' VACULM CYLINDER MAN RATING

FINAL DESIGN REPORT

CONTRACT NO. NAS 1-5311

GENERAL ELECTRIC COMPANY
Missile & Space Division
Valley Forge Space Technology Center
P. O. Box 8555
Philadelphia 1, Pennsylvania

NASA/LANGLEY 55' VACUUM CYLINDER MAN RATING

FINAL DESIGN REPORT

CONTRACT NO. NAS 1-5311

GENERAL ELECTRIC COMPANY
Missile & Space Division
Valley Forge Space Technology Center
P. O. Box 8555
Philadelphia 1, Pennsylvania

TABLE OF CONTENTS

IV APPENDICES (cont'd)

NASA/LANGLEY 55' VACUUM CYLINDER

MAN RATING DESIGN REPORT

I. SUMMARY

The equipment and services described here permit the NASA/Langley 55' Vacuum Cylinder to be utilized as a Man Rated Chamber such that men equipped with pressurized suits can be assigned to perform tasks within the Chamber representative of those required for servicing and repair of spacecraft in orbit and on extraterrestrial surfaces, for exploration on these surfaces utilizing self and vehicle locomotion, and for establishment of shelters and bases needed for protection and research. The designs presented here have been performed in accordance with the requirements of ARTC-41 and work statement L-5669 (Appendix J). The necessary services and equipment can be divided conveniently into seven major categories or systems exclusive of the repressurization and man-lock systems which are considered a part of the vacuum cylinder per se and thus not considered in design detail as part of this program. The seven systems, their respective design considerations, and procurement specifications, are discussed separately (Appendix A thru G) in the order indicated below:

A. Appendix A & B

Environmental Control System (ECS) & Rescue Environmental Control System (RECS)

Complete ECS detail design through engineering layout definition. All components specified including detailed design for those components "special" for the job, (i.e., CO_2 canister, umbilical connector). Off-the-shelf

components are specified by manufacturer's part number and performance characteristics. The RECS is defined in a similar fashion except that an engineering layout is not included. However, it is noted that the general arrangement of the defined components will be similar to the ECS layout.

B. Appendix C

Umbilical Assembly

Design complete through engineering lay-out stages with detailed drawings for connector, suit adapter harness and test fittings.

C. Appendix D

Biomedical Instrumentation

Complete definition on a component-by-component basis with procurement specifications for each component.

D. Appendix E

Control Consoles

Design lay-outs of the overall console panel including electrical schematics and specification of components (by manufacturer and part number) for all instrumentation and controls.

E. Appendix F

Biomedical Facilities

Detail definition of all equipment and furnishings required for the biomedical facilities (treatment, recovery and preparation areas). All equipment specified by manufacturer and part number. No lay-outs are provided since arrangement will be left up to the responsible physician and his staff. Existing planned facility lay-outs for biomedical facilities are adequate so far as floor space requirements are concerned.

F. Appendix G

Preparation and Check-Out Equipment (Denitrogenization Equipment)

Design lay-outs with detail definition by manufacturer and part number of all components (all components are available "off-the-shelf" for this system).

The primary purpose of the following section is to reiterate the man rating ground rules and general considerations that were evolved during the course of the program and present a technical description of the overall services and facilities as well as modifications to the chamber and its existing facilities that must be implemented to satisfy the systems requirements specifications above. The ground rules that are discussed here supplement those evolved during previous Man Rating Studies that were performed by General Electric (i.e., AEDC MK I and II Chambers, MSC Houston "A" and "B" Chambers and G.E.'s Space Simulator at Valley Forge). Complete detailed cost estimates for these items are included in Section III. A manlock requirements spec. (Appendix K) and a rapid repressurization system requirements spec. (Appendix L) are appended as well. Design drawings and lay-outs are tabulated in Appendix H.

II. GENERAL CONSIDERATIONS AND GROUND RULES

A. Chamber, Manlocks and Environmental Control Systems

As a result of several discussions and based upon previous Man Rating Studies (Ref. 1), a dual/parallel manlock installation is to be provided. The dual/parallel manlock installation gives the most flexible manlock installation and is also the most desirable from the personnel safety standpoint when

emergency repressurization is not the primary rescue mode. Detail discussions of the pros and cons of the various manlock configurations are given in Reference 1.

Design criteria for each of the parallel manlocks have been developed from a previous program (i.e., the AEDC Mark II Biomedical Study). These criteria may be found in Appendix K. Rescue operational modes for the chamber are as follows: Rescue personnel (unsuited) enter the rescue manlock and it is pumped down to some intermediate pressure, say that corresponding to 25000' altitude. The rescue lock has provisions for thermal control and control of atmosphere gas composition by means of the Rescue Environmental Control System (RECS). Now when emergency repressurization becomes necessary the chamber rapidly repressurizes to the intermediate altitude (25000', for example). The rescue lock and chamber pressures are equalized and the rescue personnel enter the chamber, sustained by oxygen masks. Chamber pressure may then be brought to sea level slowly and the evacuation of the afflicted personnel may then be effected.

The pressure suited test personnel utilize the second manlock (test manlock) as a separate independent chamber ingress/egress path. This test manlock permits their being sustained by remote environmental control systems (ECS's) via umbilicals. Each of the two test personnel is sustained by a separate ECS. After the test crewman enter the lock and it is pumped down to chamber pressure, the chamber-to-manlock door is opened, the suited personnel enter the chamber and perform umbilical switchover. The chamber umbilicals that they switch to are attached to the same ECS as the manlock umbilicals. Thus, each man is sustained by

the same ECS during ingress, task performance in the chamber, and egress. The point can be brought up here again that in short term tests it is possible to make the manlock umbilical long enough so that the test personnel can enter the chamber and perform test sequences while still being sustained by the manlock umbilicals if they are made long enough and it is not a requirement to close the manlock-to-chamber door. This does away with the need for potentially hazardous umbilical switchover tasks. A second alternate umbilical configuration that permits shutting the chamber/manlock door, yet doesn't require an umbilical switchover has been investigated and appears to be feasible. Conceptual layouts for this umbilical configuration and a suggested umbilical support boom are included. (Dwg. no's. 253E552 and SK56152-852).

With regard to the Rescue ECS used to support the rescue crew lock, it is sized to handle the metabolic heat loads of two men plus any heat loads from lights within the manlock. External heat loads from the room surrounding the manlock should be negligible since this room is assumed to be adequately air conditioned by the facility systems. Based on the floor area requirements of the manlocks indicated in the manlock criteria (Appendix K) it appears that available floor space is not adequate and the addition of more building space is recommended.

As mentioned previously, the environmental control systems to sustain the suited test personnel are each a one-man system and operate as closed loops. The ventilating/breathing oxygen stream is continuously recirculated between the suit and the ECS via an umbilical pair. Detail design considerations for the RECS and Test ECS are discussed in detail in Appendix A and B. An open loop system (i.e., continuously dumping ventilating oxygen

overboard from the suit) was not used in this case for the following reasons. An open loop system wastes considerable amounts of oxygen since a substantial flow rate (25 to 100 lbs/hr) is required to satisfactorily cool each suited subject. Furthermore, a separate vacuum system connected to the suits by umbilicals would have to be utilized to handle the oxygen exhausted from the suit. If the suit were to exhaust directly into the chamber, the ventilating flow rate would overtax the chamber pumping system. In addition, a closed system makes it possible to obtain subject viability test data such as O_2 consumption rates, CO_2 production and metabolic heat output.

In the case of the Langley Cylinder, emergency repressurization may be utilized as the primary rescue mode. For this specific case it is felt that the alternate single manlock configuration and operational mode discussed below would provide an acceptable second choice for use in this facility. It must be emphasized that this alternate configuration applies to this facility only and only for short term testing. Operation of the facility in this mode would result in somewhat limited capabilities but it does satisfy the requirements stipulated in the work statement, Appendix J, and gives adequate safety provisions from a technical viewpoint. The ground rules for the alternate mode, single manlock configuration would be:

1. Chamber repressurization (at a rapid rate in the case of critical emergencies) would be utilized as a primary mode of rescue. This is possible due to the fact that the chamber does not have a simulated solar source nor any cryo-panel installation, thus no fogging problems to hamper rescue are encountered when the chamber is repressurized. Also the tests planned would be of short duration so that an abort would not result in

the invalidation of large amounts of test data, as might be the case where longer term, more complex tests, were terminated due to repressurization.

2. Tests planned would not require rescue crew change procedures.

For these specific ground rules, a single manlock installation with rescue personnel outside the chamber (not in the single manlock) results in only two persons being exposed to a hazardous environment. Also by emergency repressurizing to a full atmosphere the rescue personnel can enter and perform their rescue tasks unincumbered by any breathing masks, pressure suits, or other paraphenalia. Although it is true that most other space simulation chambers do utilize or plan to utilize rescue personnel who are in a manlock chamber at reduced pressure, this is only because repressurization is <u>not</u> available or feasible as a primary rescue mode as may be the case for the Langley cylinder. In the case of a <u>critical</u> emergency (i.e., one that would require <u>emergency</u> repressurization) the time increment required to get to the affected test personnel within the Langley cylinder would be no greater than that possible with other chambers which have rescue personnel stationed in a lock, and are emergency repressurized to a full atmospheric pressure. Thus on the basis of available data, man rating the Langley cylinder with a single manlock and rescue personnel stationed outside the chamber is justifiable from both the viewpoints of personnel safety and of conforming with the standards of the industry, such as they are (ARTC-41), etc.). The dual parallel manlock system provides this capability as an alternate mode if it is found to be advantageous for some tasks.

B. Monitoring and Control Systems

The Biomedical Control Console arrangements, the Test Conductor Console Layout, the airlock environment controls and displays and the other necessary monitoring/control displays have been worked out as the result of several discussions between NASA/Langley and G.E. personnel. The design considerations, and procurement specifications for these items are presented in Appendix E.

The console configurations are modular and designed such that the panels can be removed from the control room if the need arises for use on other test sites. The agreed upon location permits direct visual monitoring of the tests subjects in the chamber with closed circuit TV to monitor blind areas and closed circuit TV monitoring of rescue personnel in the manlock by the biomedical observers and other test conductor personnel. The control console complex will be located on a second level above the manlocks. Layouts of the console displays are tabulated in Appendix H.

The test conductor's console also includes the control for initiating the emergency rapid repressurization sequences. Criteria for this control system are specified in Appendix L. Biomedical Instrumentation considerations are presented in Appendix D.

C. Biomedical Facilities

The biomedical facility layout indicated on the first floor plan layout of the Dynamics Research Laboratory (VDB-1-18-65) are adequate. However, it is felt that the pre-breathing and ready room areas delineated

separately on the sketch should be combined and denoted as the pre-breathing and suit checkout area. This room will include stations for personnel denitrogenation. Oxygen breathing masks and suitable aviator's high pressure storage equipment (provided by means of high pressure oxygen cylinders) are necessary. The ventilating air requirement for the suited subjects is provided by means of a high performance blower. The blower inducts ambient room air and circulates it through the suits and then it is exhausted back into the room. The facility air conditioner is assumed to be sized to handle the metabolic load of the test subjects. The blower should be located outside of the room, preferably outside of the building since blowers with the performance characteristics indicated above operate at comparatively high noise levels. Suit checkout procedures including biomedical instrumentation checkout are also accomplished in this room. Design considerations for this equipment and the required procurement specifications are given in Appendix G. As agreed previously the suit to be utilized in the chamber has not been selected, all suit accessory equipment is designed to be "universal". Thus, detailed definition of suit checkout equipment cannot be made.

III. COST ESTIMATES

The cost estimates tabulated on the following pages reflect the manpower and materials necessary to complete detail design (where necessary), fabrication, assembly, acceptance testing and installation of the equipment delineated in Appendix A thru G. Following is a summarized listing by system of total costs for the seven systems. Detailed material cost sheets are included to substantiate the materials costs indicated in the summarized lists.

A. Suit Environmental Control Systems:

Manpower Estimates: (For 2 systems)			
Engrg. Man Hours:	480 x $15.00/hr*	=	$7200.00
Drftg. Man Hours:	560 x $8.75/hr*	=	4900.00
Shop & Technician:	800 x $8.25/hr*	=	6600.00
	Total Labor		18,700.00
Material Cost (See detailed cost sheets for substantiation)			50,019.66
Total Cost (Less G & A, Fee)			$68,719.66

*Hourly rates indicated are representative of the industry and include overhead billing.

B. Rescue Environmental Control System:

Manpower Estimates:

Engrg. Man Hours:	560 x $15.00/hr.	=	$8400.00
Drftg. Man Hours:	720 x $8.75/hr.	=	6300.00
Shop & Technician:	560 x $8.25/hr.	=	4620.00
			19,320.00
	Total Labor		
Material Cost (Ref., Detailed Cost substantiation sheet)			16,844.56
Total Cost (Less G & A, Fee)			$36,164.56

C. Umbilical System:

Manpower Estimates:

Engrg. Man Hours:	320 x $15.00/hr.	=	$4800.00
Drftg. Man Hours:	360 x $8.75/hr.	=	3150.00
Shop & Technician:	280 x $8.35/hr.	=	2310.00
	Total Labor		$10,260.00
Material Cost (Ref., Mat'l. Subst. Sheet)			11,825.00
Total Cost (Less G & A, Fee)			$22,085.00

D. Bioinstrumentation System

Manpower Estimates: None included for this system since all hardware is off-the-shelf. Installation and checkout costs for this equipment are included under E.

Material Costs (Ref: Mat'l. Subst. Shts.) = $34,190.00

E. Console Systems: Test Conductor, Bio-Med & Systems Control (Costs do not include any rework to the chamber in order to accomodate this hardware).

Manpower Estimates:

Engrg. Man Hours:	320 x $15.00/hr.	=	$4800.00
Drftg. Man Hours:	480 x $8.75/hr.	=	4200.00
Shop & Technician:	1040 x $8.25/hr.	=	8580.00
	Total Labor		$17,580.00
Material Cost (Ref., Mat'l. Subst. sheet)			$54,997.90
Total Cost (Less G & A, Fee)			$72,577.90

F. Biomedical Equipment Costs - Treatment & Recovery Room

(Ref., Material Substantiation Sheets) = $8008.00

G. Denitrogenization System

Manpower Estimates:

Engrg. Man Hours:	80 x $15.00/hr.	=	$1200.00
Drftg. Man Hours:	120 x $8.75/hr.	=	1050.00
Shop & Technician:	200 x $8.25/hr.	=	1650.00
	Total Labor		$3900.00
Material Cost (Ref., Mat'l. Subst. Shts.)			2407.95
Total Cost (Less G & A, Fee)			$6307.95

Grand Total Cost for the above Equipment and Services = $248,053.07

MATERIAL SUBSTANTIATION SHEET
NASA/LRC Man Rating PROPOSAL/ PROGRAM
NAME,
FORM 1-9504 (11-65)

PREPARED BY: D. J. Withey
SHOP ORDER NO. (IF ANY): -

B LEVEL OPERATION NO.: 7280 | TASK NO.: | DESCRIPTION: SUIT ECS | DATE: 11/16/65

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBS)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
1			2	CO_2 Adsorber Canister	SCV	Similar to EBS* 113C8504		454.81	909.62
2			2	Blower	PP	Vendor Quote		1,152.25	2,304.50
3			2	Heat Exchanger	SCV	Similar to EBS 103C4137		942.55	1,885.10
4			2	Condensate Tank	SCV	Similar to EBS 103C4138G1		76.00	152.00
5			2	Reheater	SCV	Housing similar to heat exchanger heating element - vendor catalog		766.00	1,532.00
6			2	Vacuum Pump	PP	Vendor Quote		885.00	1,770.00
7			2	Solenoid Valve, SV-5	PP	Vendor Catalog		65.00	130.00
8			2	Manual Valve, MV-4	PP	Vendor Catalog		11.30	22.60
9			6	Manual Valve, MV-1, MV-2, MV-3	PP	Vendor Catalog		11.45	68.70
10			2	Relief Valve, RV-1	PP	Vendor Quote		800.00	1,600.00
11			2	Venturi Flowmeter	SCV	Similar to Lab Flowmeters		1,000.00	2,000.00
12			2	Air Flow Control, inc. 2 butterfly air valves and control box	PP	Vendor Quote		2,236.00	4,472.00
13			2	Pump, P-4	PP	Previous purchase		35.00	70.00
14			2	Flowmeter, FM-1	PP	Vendor Catalog		39.00	78.00
								TOTAL DOLLARS	

* Emergency Breathing & Suit Pressurization System
△ For both ECS's (i.e., for 2 one man systems)

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO. DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

NAME PROPOSAL/ PROGRAM

FORM I-9504 (11-60)

PREPARED BY

SHOP ORDER NO. (IF ANY)

B LEVEL OPERATION NO. | TASK NO. | DESCRIPTION SUIT ECS | DATE

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBS)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
15			2	CO_2 Analyzer	PP	Vendor Quote		1395.00	2790.00
16			2	O_2 Analyzer	PP	Vendor Quote		1385.00	2770.00
17			4	Pressure Transducer, PT-1,PT-3	PP	Vendor Quote		468.00	1872.00
18			2	Pressure Transducer, PT-2	PP	Vendor Quote		423.00	846.00
19			9	Temp. Transducer, TT-1,3,4,5,6	PP	Vendor Quote		30.85	277.65
20			2	Temp. Transducer, TT-2	PP	Vendor Quote		785.00	1570.00
21			2	Pressure Switch, APS-1	PP	Vendor Quote		40.00	80.00
22			2	Refrigeration Unit	PP	Vendor Quote		815.00	1630.00
23			3	Pump, P-1, P-3	PP	Vendor Quote		208.00	624.00
24			3	Relief Valve, RV-2, RV-3	PP	Vendor Quote		68.00	204.00
25			2	Relief Valve, RV-4	PP	Vendor Quote		68.00	136.00
26			2	Pump, P-2	PP	Vendor Quote		125.00	250.00
27			5	Manual Valve, MV-5, 6 & 7	PP	Vendor Catalog		11.70	58.50
28			5	Flowmeters, FM-2, 3 & 4	PP	Vendor Quote		91.50	457.50

TOTAL DOLLARS

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

_____ PROPOSAL/ PROGRAM

(NAME)

FORM 1-9504 (1-68)

PREPARED BY

SHOP ORDER NO. (IF ANY)

B LEVEL OPERATION NO.	TASK NO.	DESCRIPTION	DATE
		SUIT ECS	

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. SUB-CONT. MISC.	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
29			3	Suit Temp. Control, Incl. selector, control box, sensor and valve	PP	Vendor Quote		2413.25	7239.75
30			8	DPS-1 thru DPS-4 Differential Pressure Switch	PP	Vendor Quote		51.50	412.00
31			4	Regulator, R-1, R-2	PP	Vendor Catalog		38.00	152.00
32			2	Regulator R-3	PP	Vendor Catalog		66.70	133.40
33			6	Pressure Transducer, PT-4,5,6	PP	Vendor Quote		450.00	2700.00
34			2	Check Valve, CV-1	PP	Vendor Catalog		5.90	11.80
35			6	Solenoid Valve, SV-1,2,3	PP	Vendor Catalog		15.00	90.00
36			2	Solenoid Valve, SV-4	PP	Vendor Catalog		15.75	31.50
37			2	Regulator, R-4	PP	Vendor Catalog		215.00	430.00
38			100 ft.	Aluminum Pipe, 1 ½"	RM	Vendor Catalog		68.72	68.72
39			108	Flanges, 1 ½", AL	PP	Vendor Catalog		5.45	588.60
40			24	90° Beno, 1 ½" AL Pipe	PP	Vendor Catalog		3.90	93.60
41			4	T's, 1 ½" AL pipe	PP	Vendor Catalog		10.60	42.40
42			8	Unions, 1 ½" AL Pipe	PP	Vendor Catalog		4.74	37.92
								TOTAL DOLLARS	

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

NAVE PROPOSAL/ PROGRAM

FORM 1-950M (11-69)

PREPARED BY

SHOP ORDER NO. (IF ANY)

B LEVEL OPERATION NO. | TASK NO. | DESCRIPTION: SUIT ECS | DATE

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBS)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
43			54	Gaskets	PP	Vendor Catalog		0.70	37.80
44			4	Special Flange for Air Valve	PP	Engineering Estimate		25.00	100.00
45			2	Special Pipe (Blower inlet)	PP	Engineering Estimate		50.00	100.00
46			2	Special Pipe (Vacuum Pump)	PP	Engineering Estimate		25.00	50.00
47			4	Flexible Coupling	PP	Engineering Estimate		35.00	140.00
48			300	Fitting	PP	Engineering Estimate		3.00	900.00
49			2	Tubing	PP	Engineering Estimate		50.00	100.00
50			2	Structure	PP	Engineering Estimate		3,000.00	6,000.00

TOTAL DOLLARS: 50,019.66

R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

* JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

NASA/LRC MAN RATING ~~PROPOSAL~~ / PROGRAM

(NAME)

FORM 1-9504 (11-68)

PREPARED BY: D. Withey

SHOP ORDER NO. (IF ANY):

B LEVEL OPERATION NO.	TASK NO.	DESCRIPTION	DATE
		RECS	

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBS)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
1			1	CO_2 Adsorber Cannister	SCV	Similar to EBS* 113C8504		454.81	454.81
2			1	Purge Valve	SCV	Similar to EBS 689E673		1056.00	1056.00
3			1	Blower, Joy	PP	Vendor Quote		316.00	316.00
4			1	Heat Exchanger	SCV	Similar to 825D204		1230.00	1230.00
5			1	Condensate Tank	SCV	Similar to EBS 103C4138G1		76.00	76.00
6			1	Reheater housing	SCV	Similar to heat exchanger		724.00	724.00
7			1	Heating Element	PP	Vendor Catalog		47.00	47.00
8			1	Venturi Flowmeter (incl. cal.)	SCV	Similar to Lab flowmeters		1000.00	1000.00
9			1	Pump, P-1	PP	Previous purchase		35.00	35.00
10			1	Flowmeter, FM-1	PP	Vendor Catalog		39.00	39.00
11			1	O_2 Analyzer	PP	Vendor Quote		1395.00	1395.00
12			1	CO_2 Analyzer	PP	Vendor Quote		1385.00	1385.00
13			1	Refrigeration Unit	PP	Vendor Quote		1112.00	1112.00
14			1	Pump, P-2	PP	Vendor Quote		208.00	208.00
15			1	Relief Valve, RV-1	PP	Vendor Quote		68.00	68.00

* Emergency Breathing and Suit Pressurization Design

TOTAL DOLLARS

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

_____ PROPOSAL/ PROGRAM

NAME)

B

PREPARED BY

FORM 1-9504 11-61

SHOP ORDER NO. (IF ANY)

B LEVEL OPERATION NO.	TASK NO.	DESCRIPTION	DATE
		RECS	

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBS)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
16			1	Flowmeter, FM-2	PP	Vendor Quote		91.50	91.50
17			1	Manual Valve, MV-1	PP	Vendor Catalog		11.70	11.70
18			1	N_2 regulator, R-2	PP	Vendor Catalog		38.00	38.00
19			1	Solenoid valve, SV-4	PP	Vendor Catalog		13.50	13.50
20			1	O_2 regulator, R-1	PP	Vendor Quote		125.00	125.00
21			1	Solenoid Valve, SV-1	PP	Vendor Catalog		20.50	20.50
22			1	Solenoid Valve, SV-2	PP	Vendor Catalog		16.00	16.00
23			1	Solenoid Valve, SV-3	PP	Vendor Catalog		27.50	27.50
24			3	Manual Valve, MV-2, 3 & 4	PP	Vendor Catalog		11.45	34.35
25			1	Pressure Transducer, PT-2	PP	Vendor Quote		423.00	423.00
26			2	Pressure Transducer, PT-1 & 3	PP	Vendor Quote		468.00	936.00
27			2	Temperature Transducer TT-1 & TT-3	PP	Vendor Quote		30.85	61.70
28			2	Pressure Transducer, PT-4 & 5	PP	Vendor Quote		450.00	900.00
29			1	Temperature Transducer, TT-2	PP	Vendor Quote		785.00	785.00
30			1	Misc., incl structure, piping fittings	PP	Engineering Estimate		4215.00	4215.00
								TOTAL DOLLARS	16,844.56

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

LANGLEY CHAMBER (NAME) PROPOSAL/ PROGRAM

FORM 1-9504 (11-60)

C SHT. 1 OF 2

PREPARED BY W. FUNSCH

SHOP ORDER NO. - (IF ANY)

B LEVEL OPERATION NO.	TASK NO.	DESCRIPTION UMBILICAL ASSY.	DATE

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBS)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
1			2	P1 Umbilical Assembly		Vendor Quote R. E. Darling Company		$ 1490	2980
				less coupler (55 ft.)		Bethesda, Maryland			
				Dwg. 113C8797					
2			2	P2 Umbilical Assembly		Vendor Quote R. E. Darling Company		$ 685	1370
				less coupler (15 ft.)		Bethesda, Maryland			
				Dwg. 113C8797					
3			3	P3 Umbilical Assembly		Vendor Quote R. E. Darling Company		$ 580	1740
				Less Coupler (10 ft.)		Bethesda, Maryland			-
				Dwg. 113C8797					
4			7	Umbilical coupler		Engineering Estimate		$ 413	2891
				assembly (suit end)					
				Dwg. 201R801					
5			2	Umbilical coupler		Engineering Estimate		$ 722	1444
				assembly (WYE fitting)					
				Dwg. 201R801					

TOTAL DOLLARS See next pg

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

LANGLEY CHAMBER (NAME) PROPOSAL/ PROGRAM

FORM 1-950 (5-68) C SHT 2 OF (2)

PREPARED BY: W. FUNSCH

SHOP ORDER NO. (IF ANY):

B LEVEL OPERATION NO. | TASK NO. | DESCRIPTION: UMBILICAL ASSY | DATE

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBS)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
6			2	Suit Harness		Catalog Price		$ 24.	48
				Dwg. 201R806					
7			2	Umbilical Test Fixture		Engineering Estimate		$ 492	984
				Dwg. 101D1344					
8			2	Umbilical cover & restraint		Engineering Estimate		$ 200	400
				Dwg. 253E551					

TOTAL DOLLARS: 11,825

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

Langley Chamber PROPOSAL/ PROGRAM

NAME)

FORM 1 9504 (11-60) Bioinstrumentation System D

PREPARED BY: H. Josephs

SHOP ORDER NO. (IF ANY)

B LEVEL OPERATION NO.: 7280

TASK NO.:

DESCRIPTION: TEST SUBJECT (ECS" BIOINSTRUMENTATION SYSTEM

DATE:

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBO)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA Gulton Quote	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
1			2	Heart Rate and ECG Transducer		Gulton M-11		45	90
2			2	Deep Body Temp. TXDCR		" M-20040		24	48
3			2	Skin Temp. TXDCR		" M-20060		31	62
4			2	Resp. Rate TXDCR		" M-32CB2A		45	90
5			2	Suit Press. TXDCR		" P-1006		345	690
6			2	Suit Temp. in TXDCR		" M-20090		75	150
7			2	Suit Temp. out TXDCR		" M-20090		75	150
8			2	Heart Rate and ECG Preamplifier		" M-284		340	680
9			2	Respiration Rate Preamplifier		" M-284-RESP		320	640
10			2	Suit Pressure Preamplifier		" M-284BP		430	860
11			2	Heart Rate and ECG Display and Alarm Module		" M-20453		1595	3190
12			2	Deep Body Temperature Display and Alarm Module		" M-23055		820	1640
13			2	Skin Temperature Display and Alarm Module		" M-23056		870	1740

TOTAL DOLLARS: See Next Pg.

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

Langley Chamber _____ PROPOSAL/ PROGRAM

FORM I-9504 (1-64) Bioinstrumentation System D

PREPARED BY: H. Josephs

SHOP ORDER NO. (IF ANY):

B LEVEL OPERATION NO.: 7280

TASK NO.:

DESCRIPTION: TEST SUBJECT (ECS) BIOINSTRUMENTATION SYSTEM

DATE:

ITEM NO.	OPER. NO. SELF WBS	OPER. NO. SUB WBS	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
14			2	Respiration Rate Display and Alarm Module		Gulton M-24052		945	1890
15			2	Suit Pressure Display and Alarm Module		" M-20253		695	1390
16			2	Suit-Temp.-In, Display and Alarm Module		" M-23057		870	1740
17			2	Suit-Temp.-Out, Display and Alarm Module		" M-23058		870	1740
18			2	Junction Box		" M-705		420	840
19			2	Four Module Rack Inserts @ 150 per module		" M-284		600	1200
20			2	Power Supply Module		Gulton M-29951		375	750
21			1	Battery Operated Bioinst. System Calibration		" M-780		500	500

TOTAL DOLLARS: 20,080

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

Langley Chamber (NAME) PROPOSAL/ PROGRAM

FORM 1-[illegible]-63. D

PREPARED BY: H. Josephs

SHOP ORDER NO. (IF ANY):

B LEVEL OPERATION NO.:

TASK NO.:

DESCRIPTION: RESCUE PERSONNEL (RECS) BIOINSTRUMENTATION SYSTEM

DATE:

ITEM NO.	DEPT. NO. SELF	DEPT. NO. OTH. W.BO.	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
1			2	Heart Rate and ECG Transducer		Gulton M-11		45	90
2			2	Deep Body Temp. Transducer		" M-20040		24	48
3			2	Skin Temp. TXDCR		" M-20060		31	62
4			2	Respiration Rate TXDCR		" M-32CB2A		45	90
5			2	Respiration Rate Preamplifier		" M-284 RESP.		320	640
6			2	Heart Rate and ECG Display and Alarm Module		" M-20453		1595	3190
7			2	Deep Body Temp. Display and Alarm Module		" M-23055		820	1640
8			2	Skin Temp. Display and Alarm Modules		" M-230S6		870	1740
9			2	Respiration Rate Display and Alarm Module		" M-240S2		945	1890
10			2	Junction Box		" M-765		420	840
11			2	Four Module Rack Inserts @ 150 Per Module		" M-284		600	1200

TOTAL DOLLARS: See Next Page

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

Langley Chamber NAME — PROPOSAL/ PROGRAM D

PREPARED BY: H. Josephs

FORM 1-9504 (11-60)

SHOP ORDER NO. (IF ANY)

B LEVEL OPERATION NO.: 7280 | TASK NO. | DESCRIPTION: RESCUE PERSONNEL (RECS) BIOINSTRUMENTATION SYSTEM & RF LINK OPTION | DATE

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBS)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
12			2	Power Supply Module		Gulton M-299S1		375	750
								Total dollars	12,180

NOTE: The following constitutes the cost of the defined system if RF links are used instead of hardwire connections for both test and rescue subjects.

					COST OF OBVIATED HARDWIRE EQUIP.	RF LINK COST	ADDED COST
1			2	Test Subjects Equipment	15,510	32,692	17,182
2			2	Rescue Subjects Equipment	9,100	18,682	9,582
						Total added -	26,764
						Cost for RF in lieu of hardwire system costed in this report.	

TOTAL DOLLARS

R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

* JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

Langley Chamber (NAME) PROPOSAL/ PROGRAM D

FORM 1-9504 11-60 BIOINSTRUMENTATION SYSTEM

PREPARED BY: H. Josephs

SHOP ORDER NO. (IF ANY)

B LEVEL OPERATION NO. | TASK NO. | DESCRIPTION: COMMUNICATION SYSTEM | DATE

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBS)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
						Gulton Quote			
1			2	Flush-Mounted Master		Gulton-Executone 3706-WSP		740	1480
2			6	Receptacle Ear Pieces		Gulton-Executone J18-WSP		50	300
3			2	Microphone Ear Pieces		Gulton-Executone AA5608SP		75	150
				This equipment represents what is considered a minimum for safe operation.					
				Additional slave or master units may be utilized as desired.					
								TOTAL DOLLARS	1930

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

20,080
GRAND TOTAL 12,180 = 34,190
1,930

MATERIAL SUBSTANTIATION SHEET

Langley Chamber / PROGRAM E

NAME)

FORM 1-95[illegible] (11-60)

PREPARED BY: P. J. Rader

SHOP ORDER NO. (IF ANY)

B LEVEL OPERATION NO. | TASK NO. | DESCRIPTION: CONSOLE, TEST CONDUCTOR | DATE: 11/24/65

ITEM NO.	OPER. NO. SELF WBS.	OPER. NO. OTH. (WBO.	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
1			2	Cabinet, 19-1/4H x 21-3/4W x 18 L	PP	Vendor Catalog		28.05	56.10
2			2	Cabinet, 21 H x 21-3/4 W x 18 L	PP	Vendor Catalog		29.40	58.80
3			2	Panel, 17½ H x 19 W x 1/8 T	PP	Vendor Catalog		3.50	7.00
4			2	Panel, 19-1/4 H x 19 W x 1/8 T	PP	Vendor Catalog		3.85	7.70
5			2	Meter, Pressure	PP	Vendor Quote		42.40	84.80
6			3	Meter, Temp.	PP	Vendor Quote		42.40	127.20
7			3	Recorder, Pressure	PP	Vendor Quote		1190.00	3570.00
8			3	Recorder, Temp.	PP	Vendor Quote		1190.00	3570.00
9			16	Light, Signal	PP	Vendor Catalog		.94	15.04
10			16	Switch, Pushbutton	PP	Vendor Catalog		1.86	19.76
11			16	Button	PP	Vendor Catalog		.24	3.84
12			3	Switch, Rotary	PP	Vendor Catalog		1.08	3.24
13			3	Knob	PP	Vendor Catalog		.20	.60
14			1	Meter, Pressure	PP	Vendor Quote		165.00	165.00

Note: Item no's. correspond to those shown in parts list on drawing no. 253E554.

TOTAL DOLLARS: 8,219.08

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

Sheet 1 of 1

MATERIAL SUBSTANTIATION SHEET

Langley Chamber ~~PROPOSAL~~ / PROGRAM E

(NAME)

PREPARED BY: P. J. Rader

FORM 1-9504 (11-60)

SHOP ORDER NO. (IF ANY):

B LEVEL OPERATION NO. | TASK NO. | DESCRIPTION: Console, Bio-Med (Test Subject) | DATE: 11/24/65

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBO)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
1			2	Cabinet, 19¼ H x 21-3/4 W x 18 L	PP	Vendor Catalog		28.05	56.10
2			2	Cabinet, 21 H x 21-3/4 W x 18 L	PP	Vendor Catalog		29.40	58.80
3			1	Panel, 19¼ H x 19 W x 104 T	PP	Vendor Catalog		3.85	3.85
4			2	Light, Signal	PP	Vendor Catalog		.94	1.88
5			8	Switch, Push Button	PP	Vendor Catalog		1.86	14.88
6			8	Button, Red	PP	Vendor Catalog		.24	1.92
7-8	Covered in Appendix "D" (Bio-Instrumentation)							---	---
9			1	Recorder, EKG	PP	Vendor Quote		695.00	695.00
10-15	Covered in Appendix "D" (Bio-Instrumentation)							---	---
16			1	Recorder	PP	Vendor Quote		1,820.00	1,820.00
17			1	Meter, Flow	PP	Vendor Quote		165.00	165.00
18			1	Meter, Pressure	PP	Vendor Quote		165.00	165.00
19			2	Meter, Temperature	PP	Vendor Quote		165.00	330.00
20			1	Meter, Temp. Indic.	PP	Vendor Quote		100.50	100.50
21			1	Meter, O_2 PP	PP	Vendor Quote		173.00	173.00
								TOTAL DOLLARS	3,585.93

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

Langley Chamber (NAME) PROPOSAL/ PROGRAM E -

FORM 4-9504 (11-60)

PREPARED BY: P. J. Rader

SHOP ORDER NO. (IF ANY):

B LEVEL OPERATION NO. | TASK NO. | DESCRIPTION: CONSOLE BIO-MED (TEST SUBJECT) | DATE: 11/24/65

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBS)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
22			1	Meter, CO_2 PP	PP	Vendor Quote		173	173
23			4	Housing, Four Module	PP	Vendor Quote		150	600
				Notes 1. All item no's. correspond to		parts list on Dwg. 253E553			
							Sht. 2		773.00
							Sht. 1		3,585.93

TOTAL DOLLARS: 4,358.93

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PAST NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

Sheet 2 of 2

MATERIAL SUBSTANTIATION SHEET

Langley Chamber ~~PROPOSAL~~ / PROGRAM E

NAME)

FORM 1-9504 (11-60)

PREPARED BY: P. J. Rader

SHOP ORDER NO. (IF ANY)

B LEVEL OPERATION NO. | TASK NO. | DESCRIPTION: CONSOLE BIO-MED (RESCUE PERSONNEL) | DATE: 11/24/65

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBS)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
1			3	Cabinet, 19½ H x 21-3/4 W x 18 L	PP	Vendor Catalog		28.05	84.15
2			3	Cabinet, 21 H x 21-3/4 W x 18 L	PP	Vendor Catalog		29.40	88.20
3			1	Panel, 17½ H x 19 W x .104 T	PP	Vendor Catalog		3.50	3.50
4			1	Panel, 19½ H x 19 W x .104 T	PP	Vendor Catalog		3.85	3.85
5			6	Switch, Pushbutton	PP	Vendor Catalog		1.86	11.16
6			6	Button	PP	Vendor Catalog		.24	1.44
7-8	Covered in Appendix "D" - "Bio-Instrumentation"							---	---
9			2	Recorder, EKG.	PP	Vendor Quote		695.00	1390.00
10	Items 10 thru 13 covered in Appendix "D"							---	---
13		"Bio-Instrumentation"						---	---
14			2	Recorder, 6 Channel	PP	Vendor Quote		1820.00	3640.00
15			1	Meter, Flow	PP	Vendor Quote		165.00	165.00
16			1	Meter, Pressure	PP	Vendor Quote		165.00	165.00
17			1	Meter, Temperature	PP	Vendor Quote		165.00	165.00
18			1	Meter, O_2 PP	PP	Vendor Quote		173.00	173.00
								TOTAL DOLLARS	5,890.30

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

Langley Chamber (NAME) ~~PROPOSAL~~ / PROGRAM E

PREPARED BY: P. J. Rader

SHOP ORDER NO. (IF ANY):

FORM 1-9504 (11-60)

B.E.E.L. OPERATION NO. | TASK NO. | DESCRIPTION: CAPSULE, BIO-MED (RESCUE PERSONNEL) | DATE: 11/24/65

ITEM NO.	OPER. NO. B.E.E.L. (WBS)	OPER. NO. OTH. (WBO)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
19			1	Meter, CO_2 PP	PP	Vendor Quote		165.00	165.00
20			1	Meter, Pressure	PP	Vendor Quote		165.00	165.00
21			1	Meter, Temperature	PP	Vendor Quote		42.40	42.40
22			1	Cabinet, Desk Top	PP	Vendor Catalog		257.00	257.00
23			6	Housing, Four Module	PP	Vendor Quote		150.00	900.00
				Note: All item no's. correspond to parts list on Dwg. No. 201R803					
							Sheet	2	1529.40
							Sheet 1		5890.30

TOTAL DOLLARS: 7419.70

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

Langley Chamber (NAME) PROPOSAL/ PROGRAM E

FORM 1-95[illegible]

PREPARED BY: P. J. Rader

SHOP ORDER NO. (IF ANY):

B LEVEL OPERATION NO. | TASK NO. | DESCRIPTION: Console, Systems Control | DATE: 11/23/65

ITEM NO.	OPER. NO. SELF WBS	OPER. NO. OTH. WBS	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
1			4	Cabinet (21 H x 21-3/4 W x 18 L)	PP	Vendor Catalog		29.40	117.60
2			4	Cabinet (22-3/4 H x 21-3/4W x 18 L)	PP	Vendor Catalog		30.45	121.80
3			4	Panel (19½H x 19 W x .104T)	PP	Vendor Catalog		3.85	14.40
4			4	Panel (21 H x 19W x .104 T)	PP	Vendor Catalog		4.25	17.00
5			3	Switch, Toggle, MOM	PP	Vendor Catalog		1.95	2.85
6			10	Switch, Toggle, Lock	PP	Vendor Catalog		5.28	52.80
7			29	Switch, Push button	PP	Vendor Catalog		1.86	53.94
8			29	Button	PP	Vendor Catalog		.24	6.96
9			5	Knob	PP	Vendor Catalog		.20	1.00
10			9	Light, Signal	PP	Vendor Catalog		.94	8.46
11			3	Pot, Logarithmic	PP	Vendor Quote		3.60	10.80
12			2	Pot (Supplied with ECS)	PP	Vendor Catalog		---	---
13			3	Variac	PP	Vendor Catalog		31.00	31.00
14			3	Recorder, Pressure	PP	Vendor Quote		1107.00	3321.00
15			3	Recorder, O_2 PP	PP	Vendor Quote		1082.00	3246.00
								TOTAL DOLLARS	7005.66

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT ASVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

Langley Chamber (NAME) PROPOSAL/ PROGRAM E

FORM 1-9504 11-63

PREPARED BY P. J. Bader

SHOP ORDER NO. (IF ANY)

B LEVEL OPERATION NO. | TASK NO. | DESCRIPTION CONSOLE, SYSTEMS CONTROL | DATE 11/23/65

ITEM NO.	OPER. NO. SELF WBS	OPER. NO. OTH. WBS	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
16			3	Recorder, CO_2	PP	Vendor Quote		1082.00	3246.00
17			3	Recorder, Temp.	PP	Vendor Quote		1152.00	3456.00
18			8	Meter, Tank Pressure	PP	Vendor Quote		42.40	339.20
19			2	Meter, Flow	PP	Vendor Quote		165.00	330.00
20			1	Meter, Flow	PP	Vendor Quote		165.00	330.00
21			6	Meter, Pressure	PP	Vendor Quote		165.00	330.00
22			2	Meter, O_2 Partial Pressure	PP	Vendor Quote		173.00	346.00
23			1	Meter, O_2 Partial Pressure	PP	Vendor Quote		173.00	173.00
24			3	Meter, CO_2 Partial Pressure	PP	Vendor Quote		165.00	495.00
25			3	Meter, Temp. Control	PP	Vendor Quote		165.00	495.00
26			8	Meter, Temp. Indicating	PP	Vendor Quote		100.50	804.00
27			2	Meter, Temp. Control	PP	Vendor Quote		264.50	529.00
28			2	Ammeter, AC	PP	Vendor Catalog		20.00	40.00
29			1	Ammeter, AC	PP	Vendor Catalog		22.00	22.00
30			5	Ammeter, AC	PP	Vendor Catalog		20.00	100.00
								TOTAL DOLLARS	11,035.20

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO. DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

Langley Chamber (NAME) ~~PROPOSAL~~ / PROGRAM E

FORM 1-3504 -65

PREPARED BY: P. J. Rader

SHOP ORDER NO. (IF ANY):

B LEVEL OPERATION NO. | TASK NO. | DESCRIPTION: CONSOLE, SYSTEM CONTROL | DATE: 11/23/65

ITEM NO.	ORDER NO. SELF MFG	ORDER NO. OTHER MFG	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
31			3	Adaptrol, Flow Meter	PP	Vendor Quote		16.00	48.00
32			1	Temp. Indicator (12 channel)	PP	Vendor Quote		170.00	170.00
33			1	Cabinet, Desk Top	PP	Vendor Catalog		290.00	290.00
34			1	Meter, Pressure	PP	Vendor Quote		165.00	165.00
35			2	Meter, Pressure	PP	Vendor Quote		42.40	84.80
36			3	Meter, Temp.	PP	Vendor Quote		42.40	127.20
37			4	Meter, Diff. Pressure	PP	Vendor Quote		42.40	169.60
38			2	Meter, Rate of Climb	PP	Vendor Quote		496.00	992.00
39			2	Switch, Rotary	PP	Vendor Catalog		1.08	2.16
40			13	Relays	PP	Vendor Quote		12.00	156.00
41			1	Switch DPDT	PP	Vendor Catalog		1.68	1.68
		NOTES:		1) Item no's. correspond to those shown in parts list on Dwg. No. 201R804			Sheet 3		2206.44
							Sheet 2		11035.20
							Sheet 1		7005.66
								TOTAL DOLLARS	20247.26

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

Langley Chamber (NAME) PROPOSAL/ PROGRAM E

FORM 1-9504 (11-60)

PREPARED BY: P. J. Bader

SHOP ORDER NO. (IF ANY):

'B' LEVEL OPERATION NO.: | TASK NO.: | DESCRIPTION: Chamber and Manlock Transducers | DATE: 11/24/65

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBO)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
1			4	Transducer, Diff. Press.	PP	Vendor Quote (Consol. Controls)		1550.00	6200.00
2			3	Transducer, Temp.	PP	Vendor Quote (Consol. Controls)		785.00	2355.00
3			12	Probes, Thermocouple	PP	Vendor Quote (Consol. Controls)		30.00	360.00
4			3	Transducer, ABS. Press.	PP	Vendor Quote (Consol. Controls)		493.00	1479.00

TOTAL DOLLARS: 10,394.00

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

Grand Total for E = $54,997.90

Sheet 1 of 1

MATERIAL SUBSTANTIATION SHEET

Langley Chamber (NAME) PROPOSAL/ PROGRAM F

FORM 1-95:4 (11-60)

PREPARED BY Roncevich/Thomae

SHOP ORDER NO. (IF ANY)

B LEVEL OPERATION NO. | TASK NO. | DESCRIPTION TREATMENT AND RECOVERY ROOM BIOMEDICAL EQUIPMENT | DATE

ITEM NO.	OPER. NO. SELF WBS	OPER. NO. OTH. (WBO)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
			2	Two-Crank Hosp. Bed	PP	Quotes - See Procurement List - Corresponding		170.75	341.50
			2	Hospital Mattresses	PP	Item No's on Proc. List		39.50	79.00
			1	Imperatori Treatment & Diagnostic Unit	PP			660.00	660.00
			3	Goose Neck Floor Lamp	PP			15.00	45.00
			1	Portable Resuscitator (Emerson)	PP			485.00	485.00
			2	Instrument Cabinet	PP			228.00	556.00
			1	ENT Chair	PP			89.00	89.00
			1	Ambulance Stretcher	PP			139.00	139.00
			1	Cardiac Defibrillator (AC)	PP			545.00	545.00
0			1	Waste Receiver	PP			5.70	5.70
1			1	Wheel Stretcher	PP			157.20	157.20
2			2	Surgeon's Examiner's Stool	PP			32.10	64.20
3			1	3-Panel Aluminum Folding Screen	PP			66.00	66.00

TOTAL DOLLARS 3232.60

R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

* JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

Langley Chamber (NAME) PROPOSAL/ PROGRAM

FORM 1-9504 (11-60)

PREPARED BY: Poncevich/Thomae

SHOP ORDER NO. (IF ANY):

B LEVEL OPERATION NO. | TASK NO. | DESCRIPTION: TREATMENT AND RECOVERY ROOM MEDICAL MONITORING PANEL | DATE

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBO)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
14			1	Console	PP	Vendor Catalogue		80.40	80.40
15			4	Caster	PP	Vendor Catalogue		2.50	10.00
16			1	Module, EKG	PP	Vendor Quote		995.00	995.00
17			1	Oscilloscope, EKG	PP	Vendor Quote		500.00	500.00
18			1	Module, Heart Rate	PP	Vendor Quote		695.00	695.00
19			1	Module, Resp. Rate	PP	Vendor Quote		995.00	995.00
20			1	Module, Body Temp.	PP	Vendor Quote		550.00	550.00
21			1	Module, Skin Temp.	PP	Vendor Quote		650.00	650.00
22			2	Housing, Four Module	PP	Vendor Quote		150.00	300.00
				This page -					
				NOTE: All item no's. correspond to those shown in parts list on					
				Dwg. No. 253E555					
						Total this sheet			4775.40
						Total sheet 1			3232.60

Sheet 2 of 2

TOTAL DOLLARS: $8008.00

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

SHT 1 (4)

MATERIAL SUBSTANTIATION SHEET

Langley ~~Man Rating~~ COMPUTER ~~PROPOSAL~~ / PROGRAM

NAME

FORM 1-9504 (11-60)

G

PREPARED BY: R. B. Cadman

SHOP ORDER NO. (IF ANY):

'B' LEVEL OPERATION NO.	TASK NO.	DESCRIPTION	DATE
		DENITROGENIZATION SYSTEM	

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBO	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
1			5	Oxygen regulator		Modern Engineering Co.		38.00	190.00
2			5	Oxy. Reg.-Diluter-Demand		Sierra Engineering Co.		46.15	230.75
3			5	Mask, Oxygen		Sierra Engineering Co.		24.00	120.00
4			5	Valve & Hose Connector		Sierra Engineering Co.		64.53	322.65
5			5	Connector Ass'y.		Sierra Engineering Co.		2.17	10.85
6			5	NB Hose Ass'y.		Sierra Engineering Co.		8.50	42.50
7			5	Portable Oxy. System		Sierra Engineering Co.		52.65	263.25
8			5	Hose Clamp		Sierra Engineering Co.		0.15	0.75
9			1	Pressure Relief Valve		Fisher Governor Co.		3.35	3.35
10			1	45 CFM Blower		Rotron Mfg. Co.		700.00	700.00
11			3	Electrical Connect.		Bendix Corp.		20.28	60.84
12			8	Connector, Female Tube		Swagelok		8.00	64.00
13			1	Hinged Wire Way Conn.		General Electric Supply		1.30	1.30
14			1	Hinged Wire Way - 2 Ft.		General Electric Supply		9.80	9.80
15			1	Hinged Wire Way - 4 Ft.		General Electric Supply		18.00	18.00

TOTAL DOLLARS: 2042.04

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

SHT 2 (9)

MATERIAL SUBSTANTIATION SHEET

ANGLET CHAMBER PROPOSAL/ PROGRAM
(NAME)

FORM 1-9504 (11-68)

PREPARED BY: R. B. Cadman

SHOP ORDER NO. (IF ANY)

B LEVEL OPERATION NO.	TASK NO.	DESCRIPTION	DATE

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBS)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
16			2	Closure, Hinged Wire Way		General Electric Supply		1.50	3.00
17			1	Capacitor		P. R. Mallory		4.50	4.50
18			1	Capacitor Clamp		P. R. Mallory		0.18	0.18
19			12	Terminal Blocks		Cinch Jones		0.59	7.08
20			3	Box, Outlet		General Electric Supply		0.60	1.80
21			3	4 in. Round Blank		General Electric Supply		0.17	0.51
22			4	Female Flared Fitting		Parker-Hannifin		4.00	16.00
23			2	Mercury Switch		General Electric Supply		1.69	3.38
24			6	Connector		General Electric Supply		0.37	2.22
25			1	Condulet - 2 Gang		General Electric Supply		5.50	5.50
26			1	Cover - 2 Gang Condulet		General Electric Supply		1.20	1.20
27			1	Tee		Northern Indiana Brass		2.50	2.50
28			1	Tee		Northern Indiana Brass		1.35	1.35
29			1	Tee		Northern Indiana Brass		0.94	0.94
30			4	Tee		Northern Indiana Brass		0.37	1.48
								TOTAL DOLLARS	51.64

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

MATERIAL SUBSTANTIATION SHEET

LANGLEY [illegible] PROPOSAL/ PROGRAM

NAME)

FORM 1-9504 (11-60)

G

PREPARED BY: R. B. Cadman

SHOP ORDER NO. (IF ANY)

B LEVEL OPERATION NO.	TASK NO.	DESCRIPTION	DATE

ITEM NO.	OPER. NO. SELF (WBS)	OPER. NO. OTH. (WBO)	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
31			16	Elbow		Northern Indiana Brass		0.28	4.40
32			2	Elbow		Northern Indiana Brass		5.15	10.30
33			1	Extended Bushing		Northern Indiana Brass		0.25	0.25
34			1	Male Fitting Adapter		Northern Indiana Brass		0.52	0.52
35			3	Y Pattern Globe Valve		Northern Indiana Brass		-4.30	12.90
36			3	Globe Valve		Northern Indiana Brass		2.80	8.40
37			2	Elbow		Parker-Hannifin		3.09	6.18
38			2	Elbow		Parker-Hannifin		2.76	5.52
39			3	Tee		Parker-Hannifin		7.67	23.01
40			4	Tee		Parker-Hannifin		8.00	32.00
41			2	Adapter		Parker-Hannifin		1.01	2.02
42			10ft.	1/4 Tube - Stainless		Parker-Hannifin		0.98 ft.	9.80
43			26 ft.	3/8 Tube - Stainless		Parker-Hannifin		1.25 ft.	32.50
								TOTAL DOLLARS	147.78

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSFC PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

SHT 4 (4)

MATERIAL SUBSTANTIATION SHEET
[illegible] PROPOSAL/ PROGRAM
(NAME)
FORM [illegible]

PREPARED BY
R. B. Cadman

SHOP ORDER NO. (IF ANY)

BASIC OPERATION NO.	TASK NO.	DESCRIPTION	DATE

ITEM NO.	SHEET NO.	QTY.	ITEM DESCRIPTION	*TYPE OF MATERIAL	** SOURCE USED TO OBTAIN COST DATA	*** COMPUT. HOURS	UNIT PRICE	TOTAL DOLLARS
44		2'	Tube - 2"		Northern Indiana Brass		1.96/ft.	3.92
45		4'	Thin Wall Conduit - 1"		General Electric Supply		0.31/ft.	1.24
46		4'	Tube - 1½"		Northern Indiana Brass		1.31/ft.	5.24
47		4'	Tube - 1 1/4"		Northern Indiana Brass		1.00/ft.	4.00
48		4'	Tube - 3/8"		Northern Indiana Brass		0.61/ft.	2.44
49		30'	Aero Tube, Insulation		Johns-Manville		0.24/ft.	7.17
50		28'	Tube - 3/8"		Northern Indiana Brass		0.28/ft.	7.84
51		4	Adapter - Tube to Flare		Parker-Hannifin		3.16	12.64
52		4	Valve, FPT		Hoke, Inc.		18.00	72.00
53		10	Air Filter		Fram Aire		5.00	50.00

TOTAL DOLLARS 166.49

* R.M. - RAW MATERIAL; P.P. - PURCHASED PARTS; SCV - SUB-CONTRACT VENDOR; SCGE - SUB-CONTRACT TO OTHER GENERAL ELECTRIC UNITS.

** JUSTIFY BY INDICATING PURCHASE ORDER NO., VENDOR'S QUOTE NO., DEGREE OF COMPLEXITY TO PART NO. OR DRAWING NO OF PAST OR PRESENT MSVD PROGRAM. DO NOT USE "ENGINEERING ESTIMATE" UNLESS ITEM IS COMPLETELY NEW AND ADVANCES EXISTING STATE OF THE ART. IF SUB-CONTRACT ITEM, INDICATE WORK TO BE PERFORMED BY SUB-CONTRACTOR.

*** LIST COMPUTER HOURS, IF ANY, AND INCLUDE IN MATERIAL COST.

GRAND TOTAL $2,407.95

APPENDICES A - L

APPENDIX A

SUIT ENVIRONMENTAL CONTROL SYSTEM DESIGN CONSIDERATIONS

INTRODUCTION

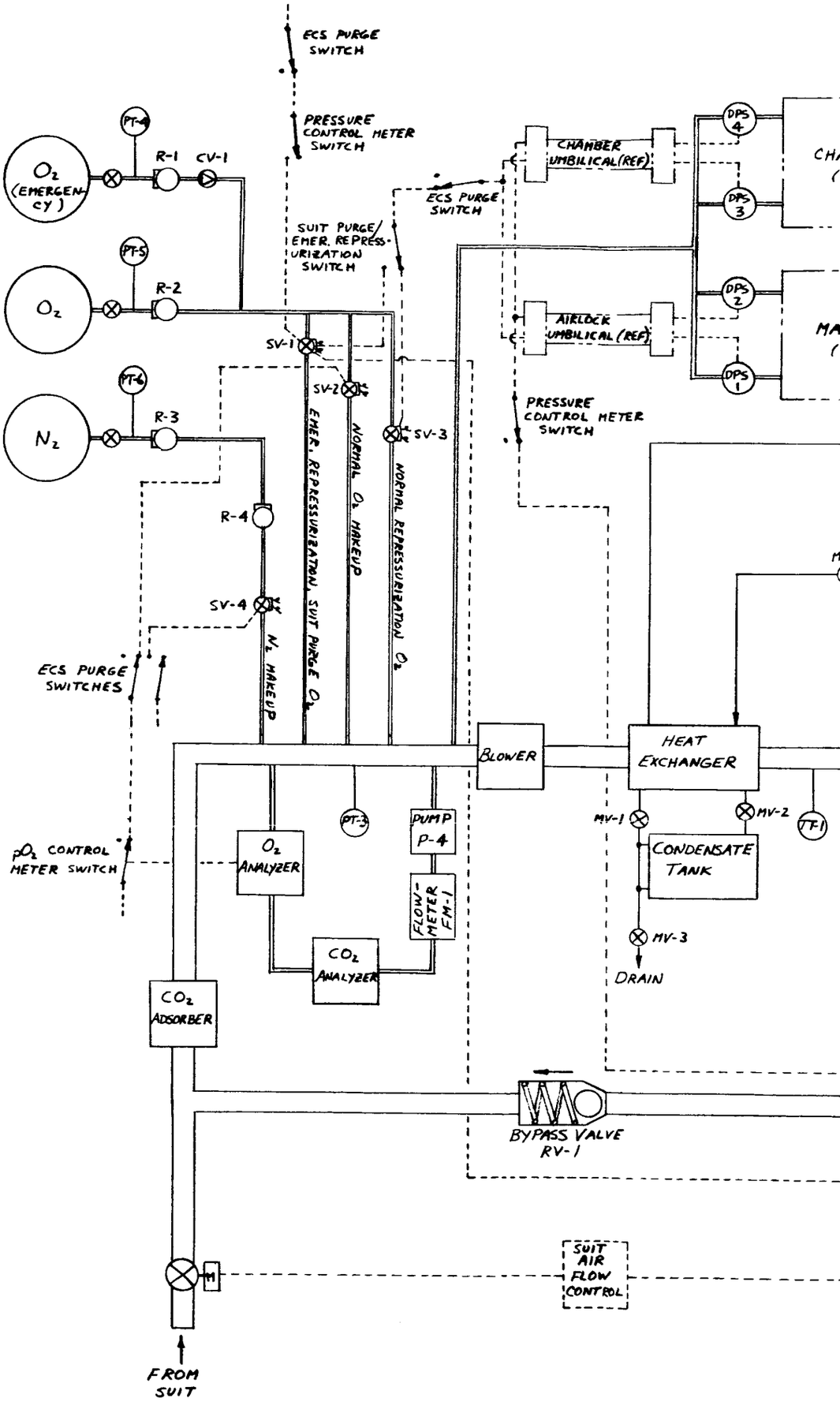
The schematic of the Suit Environmental Control System (ECS) is shown in figure 1-A. Drawing 201R803 is an engineering layout of the ECS. The main function of the ECS is to control the atmosphere environment for a man within a full pressure suit when subjected to the low vacuum environment of the NASA Langley Vacuum Cylinder. The ECS also provides liquid coolant and/or cool conditioned air to the pressure suit for metabolic heat rejection. In discussing the design of the ECS, it is simplest to separate the ECS into its three main functional subsystems; the air circulation loop, the coolant loop and the pressurization control subsystem.

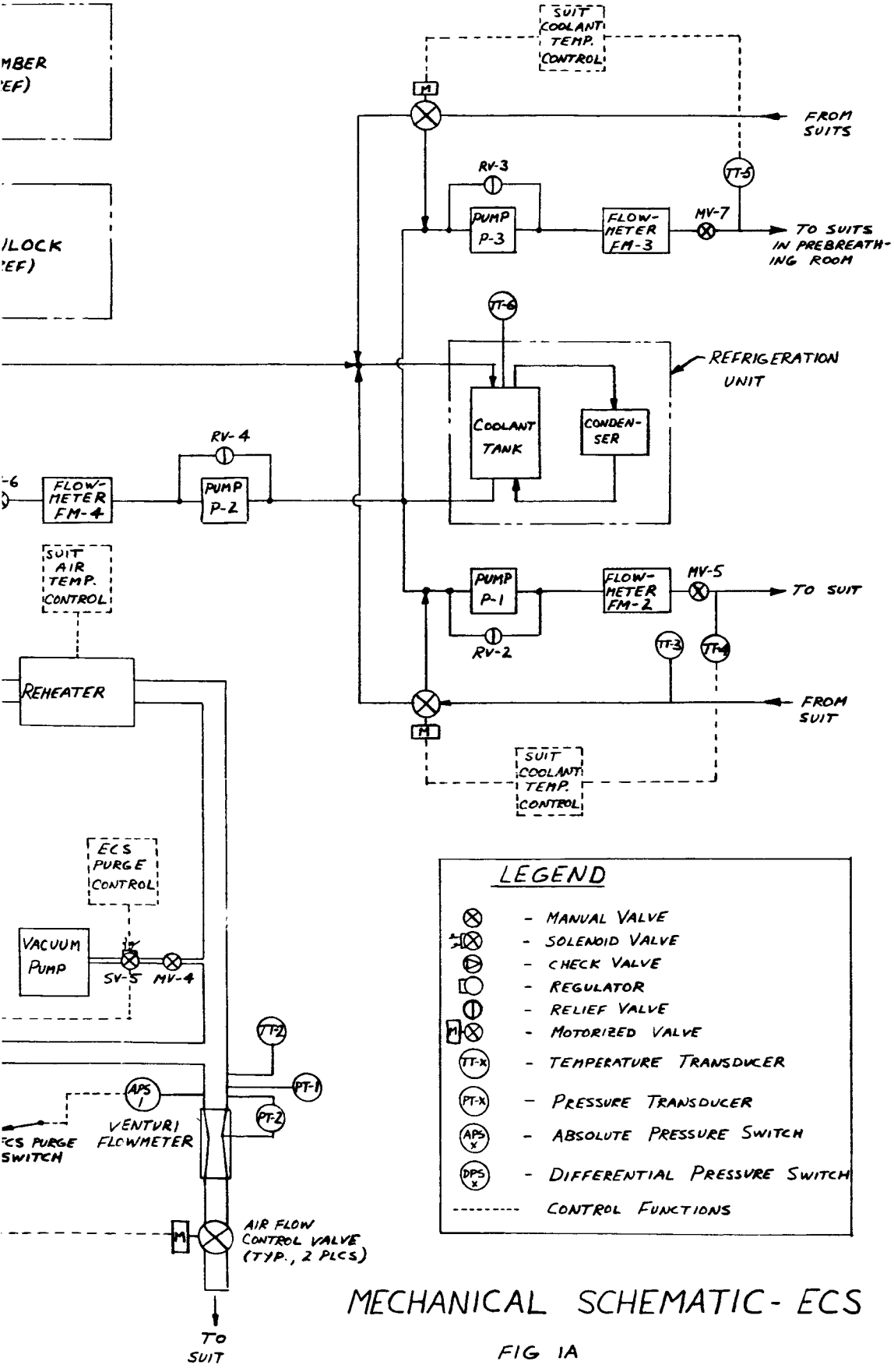
SYSTEM DESIGN

Air Circulation Loop

The function of the air circulation loop is to circulate and condition the air through the full pressure suit. With the help of the schematic (figure 1-A) the air flow can be traced through this closed loop system. Air, from the pressure suit, enters the ECS and is directed to the CO_2 absorber canister. The air from the suits has picked up moisture (latent heat), sensible heat, CO_2 and trace contaminants from the metabolic processes of the man. The air is also slightly deficient in oxygen, due to metabolic consumption. In the CO_2 absorber canister, CO_2 is removed from the air by passing the air through baralyme. The baralyme chemically combines with the CO_2 forming carbonates, and releasing water. A small charge of activated charcoal is also used in the CO_2 absorber canister to remove trace-gas impurities and odors from the air.

From the CO_2 canister, the air passes through the blower. The blower


ECS PURGE SWITCH
PRESSURE CONTROL METER SWITCH
O_2 (EMERGENCY)
PT-4
R-1
CV-1
PT-5
O_2
R-2
SUIT PURGE/ EMER. REPRESSURIZATION SWITCH
ECS PURGE SWITCH
CHAMBER UMBILICAL (REF)
AIRLOCK UMBILICAL (REF)
DPS 4
DPS 3
DPS 2
DPS 1
SV-1
SV-2
SV-3
PT-6
N_2
R-3
PRESSURE CONTROL METER SWITCH
R-4
SV-4
EMER. REPRESSURIZATION SUIT PURGE O_2
NORMAL O_2 MAKEUP
NORMAL REPRESSURIZATION O_2
N_2 MAKEUP
ECS PURGE SWITCHES
BLOWER
HEAT EXCHANGER
PT-3
PUMP P-4
MV-1
MV-2
TF-1
pO_2 CONTROL METER SWITCH
O_2 ANALYZER
FLOW-METER FM-1
CONDENSATE TANK
MV-3
DRAIN
CO_2 ADSORBER
CO_2 ANALYZER
BYPASS VALVE RV-1
M
SUIT AIR FLOW CONTROL
FROM SUIT



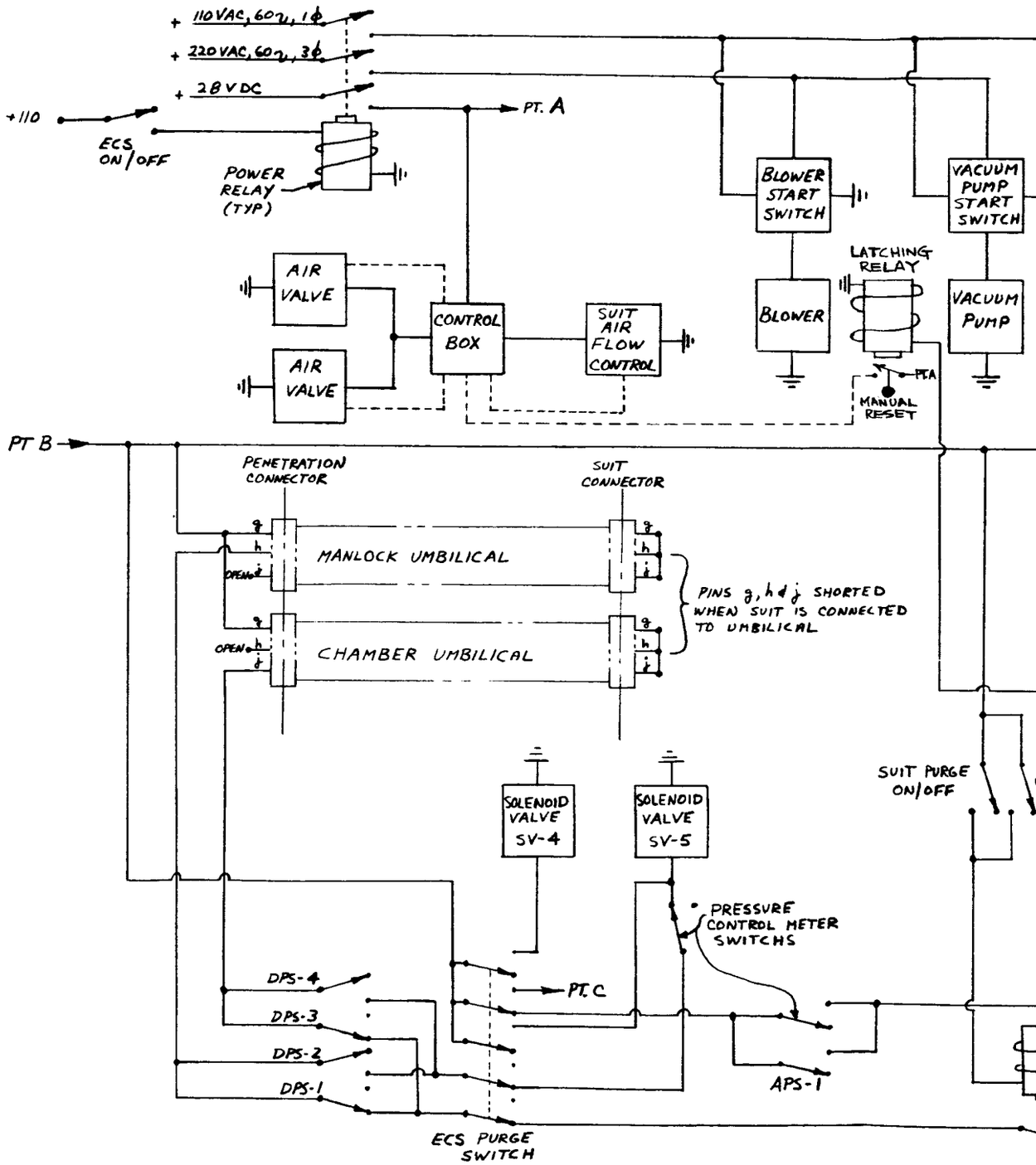
MECHANICAL SCHEMATIC - ECS

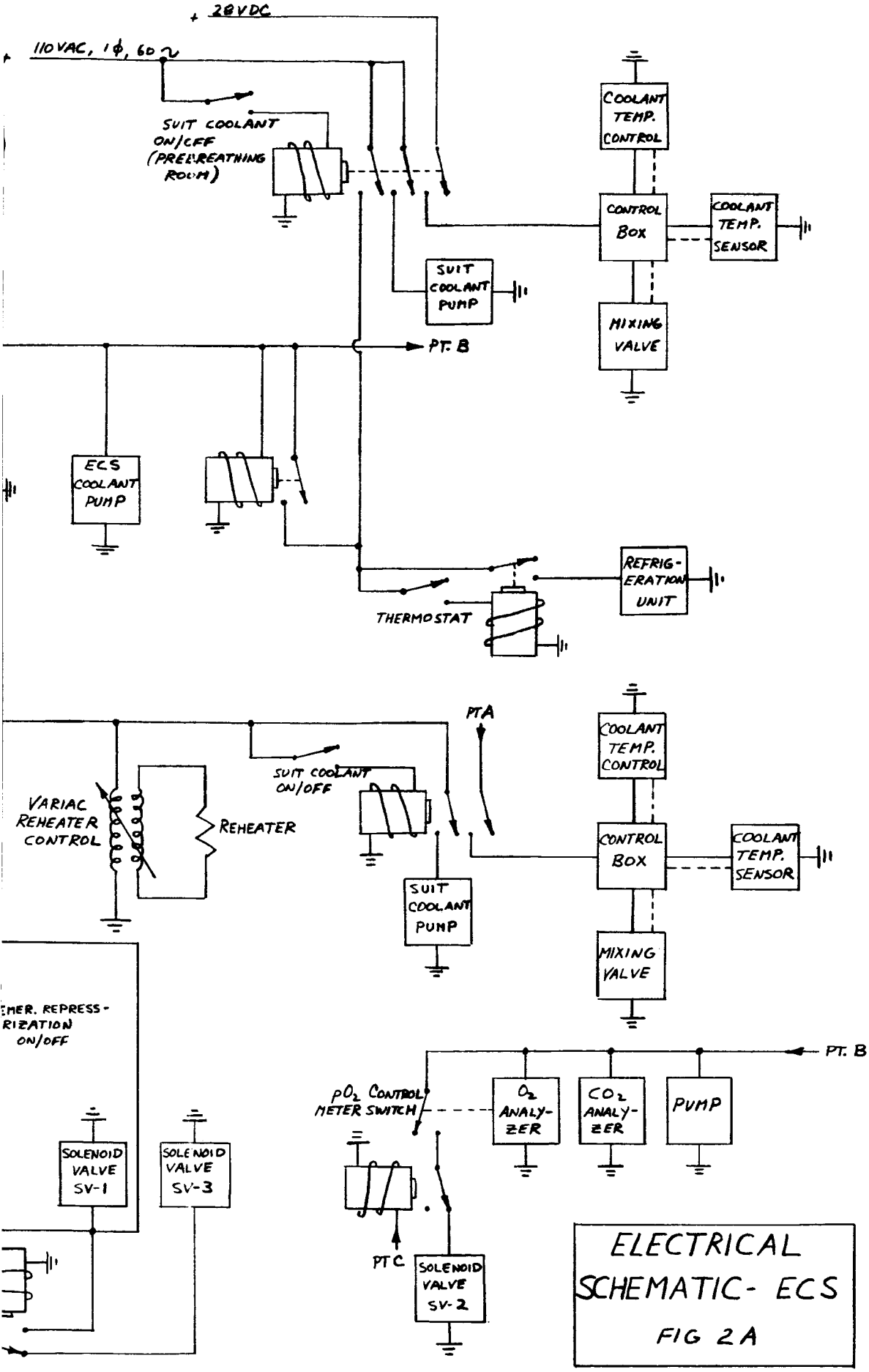
FIG 1A

DJW - 11/22/65 REV B

A-2

2


+ 110VAC, 60~, 1φ
+ 220VAC, 60~, 3φ
+ 28VDC
+110
ECS ON/OFF
POWER RELAY (TYP)
PT. A
BLOWER START SWITCH
VACUUM PUMP START SWITCH
LATCHING RELAY
AIR VALVE
AIR VALVE
CONTROL BOX
SUIT AIR FLOW CONTROL
BLOWER
VACUUM PUMP
PTA
MANUAL RESET
PT B
PENETRATION CONNECTOR
SUIT CONNECTOR
MANLOCK UMBILICAL
CHAMBER UMBILICAL
OPEN
PINS g, h & j SHORTED WHEN SUIT IS CONNECTED TO UMBILICAL
SOLENOID VALVE SV-4
SOLENOID VALVE SV-5
SUIT PURGE ON/OFF
PRESSURE CONTROL METER SWITCHS
DPS-4
DPS-3
DPS-2
DPS-1
PT. C
APS-1
ECS PURGE SWITCH



ELECTRICAL SCHEMATIC- ECS

FIG 2A

OJW 11/23/65 REV A

imparts sufficient energy to the air to circulate it through the ECS, the umbilicals and the pressure suit. Next, the air flows through the heat exchanger. The sensible and latent heat picked up by the air from the man are rejected to the coolant loop in the heat exchanger. The air leaving the heat exchanger is thus both cooled and dehumidified. Water, condensed out of the air, flows to and is stored in the condensate tank.

The cool, dry air then enters the reheater, where its temperature is raised by contact with a finned electrical heater. By varying the power input to the heater, the air temperature to the suits can be controlled. The air is then delivered to the suits through the air flow control valve.

Depending on the setting of the suit air flow control valves, and the absolute pressure of the suit, some of the air flow may be bypassed through the relief valve. That is, the air flow may split, a portion being delivered to the suit, and a portion being bypassed to the ECS inlet. The relief valve serves two functions. One, it prevents a high ΔP from occuring across the suit by limiting suit/umbilical ΔP to 2 to 2.4 PSI. Second, it acts as a bypass relief valve for the blower, preventing possible injury to that component by always allowing air flow to circulate through the system.

Suit air flow rate is controlled by the two motorized butterfly valves. Two valves, slaved together, are used, one on the inlet and one on the outlet, in order to provide a constant suit pressure when the airflow is changed.

Coolant Loop

The function of the coolant loop is to provide a heat sink for the air flow through the heat exchanger, and to provide coolant to the pressure suits when liquid cooled suits are employed. To provide this function, a refrigeration unit is utilized to maintain a reservoir of coolant (40% ethylene glycol - 60% water) at 34° F. Coolant is then drawn from this reservoir to supply the

liquid cooled suits or ECS heat exchanger.

The coolant flow through the heat exchanger is straightforward. A centrifugal pump pumps the fluid from the reservoir, through the heat exchanger, and back to the reservoir. Manual valve MV-6 is adjusted to provide the flow rate required.

The coolant flow to the suits is more complicated due to the fact that the coolant temperature to the suits must be controlled. Again a pump and manual valve are used to provide the desired coolant flow. In addition, a bypass mixing valve and temperature controller are used to control inlet temperature. The controller responds to the temperature of the coolant to the suits, and adjusts the mixing valve accordingly. The valve, by bypassing the relatively warm coolant returning from the suits, to the pump inlet, where it mixes with the cold coolant from the reservoir, maintains the coolant outlet temperature to the suits at a specified value.

On one of the ECS's, a second identical coolant circuit is provided to supply coolant to the pre-breathing room for suit cooling.

Pressurization Control Subsystem

The pressurization control subsystem maintains the selected atmosphere total pressure and oxygen partial pressure within the pressure suits. It also provides for purging the ECS and the suits with oxygen prior to chamber operation, and controls suit pressure during depressurizations and repressurizations from chamber pressure to ambient. The design of the pressurization control subsystem can best be explained by describing the sequence of events that occur in the operation of the system.

Prior to the test, the suit operating pressure is selected as well as the suit operating oxygen partial pressure (pO_2). The limit switch contacts on the

pO_2 control meter are adjusted to close at the desired pO_2 control level. If a two-gas atmosphere is required, the nitrogen regulator, R-4, is set to maintain the suit operating total pressure. If a one-gas atmosphere is required, the nitrogen cylinder valve is left closed. The limit switch contacts on the total pressure control meter (measuring blower suction pressure) are adjusted so that they open at 0.5 psi below suit operating total pressure.

The ECS is then turned on. With all components operating and the special test connector installed on the airlock umbilical, the ECS is purged by flipping the ECS purge switch to "On". This opens solenoid valve SV-5, and simultaneously cuts out all normal or emergency oxygen or nitrogen flow to the ECS. The vacuum pump them evacuates the system. This accomplished, the ECS purge switch is switched to "Off". The oxygen and nitrogen flows to the ECS are re-activated. The oxygen partial pressure control (meter contacts) opens valve SV-2, admitting oxygen to the system until the set pO_2 limit is reached. Safety switch APS-1 opens valve SV-1, admitting oxygen until the total pressure, at ECS outlet, is 3.5 psia. The low safety limit switch on the blower suction pressure meter also opens SV-1 until this limit is reached. Differential pressure switch, DPS-1, opens valve SV-3 admitting oxygen to the system until the system pressure is 1.0 psi above the manlock pressure (1.0 psi above ambient, since manlock is at ambient pressure at this time). Nitrogen regulator R-4 opens and admits nitrogen to the system until the suit total operating pressure is reached. The sum total of this process is, that, at the end of the purge cycle, the ECS pressure, at blower suction, will be 15.7 psia (assuming nominal ambient of 14.7 psia) and the atmosphere composition will be 100% O_2 if a one-gas suit atmosphere was selected or nearly 100% O2 if a two-gas suit atmosphere was selected. In this latter case, the amount of nitrogen added to the system is minimal, since the N_2 flow rate is small in comparison with the O_2 flow rate, and the N_2 flow is cut off when the suit total operating pressure is reached.

With the ECS thus operating in a pressurized condition (blower suction 15.7 psia, blower outlet 18.7 psia) the test subject, wearing an oxygen mask and with faceplate open, enters the manlock and connects to the ECS umbilical. The ECS pressure will drop, due to loss of oxygen through the open faceplate, DPS-1 will close, and valve SV-3 will open admitting oxygen to the system. The suit purge switch is then switched to"On". This connects DPS-1 to SV-1, which provides a higher oxygen flow to the system. Since DPS-1 is trying to maintain a system pressure, at blower suction, of 1.0 psi above manlock pressure, oxygen continues to flow through SV-1, flushing the suit. After a one-minute purge, the suit purge switch is returned to"Off", and DPS-1 is re-connected to SV-3. The oxygen mask is removed, the suit faceplate closed, and the ECS and suit are pressurized, by O_2 flow through SV-3, until the blower suction pressure is 15.7 psia. The suit pressure at this point is 17.2 psia (2.5 psig).

The airlock door is closed, and the airlock pumpdown started. When the differential pressure between blower suction and the airlock reaches 1.5 psi, switch DPS-2 closes, opening SV-5, allowing the vacuum pump to pump down the ECS and suit. Thus, DPS-2 working with SV-5 maintains the pressure suit at about 3.0 psig above airlock ambient when the airlock is being decompressed. When the blower suction pressure reaches 0.5 psi below the desired suit operating pressure, the pressure control meter contacts open, disconnecting DPS-2 from SV-5. The suit pressure at this time would be about 0.5 psi above the nominal operating pressure. No further pumpdown of the ECS/suit is accomplished.

When the manlock pressure equals chamber pressure, the door between the manlock and chamber is opened, and the suited subject enters the chamber. He then connects to the chamber umbilical, and disconnects from the manlock umbilical. This automatically switches the ECS and suit repressurization control from DPS-1

to DPS-3, and the depressurization controls from DPS-2 to DPS-4. Thus, when the man is in the manlock, connected to the manlock umbilical (or when the special test connector is attached to the manlock umbilical) DPS-1 and DPS-2 control the pressure of the ECS during purge, decompression (pump down) and repressurization. These two differential pressure switches are referenced to manlock ambient. However, when the man connects to the chamber umbilical, DPS-3 and DPS-4 are utilized to perform these functions. These latter two differential pressure switches are referenced to chamber pressure. This control system thus allows the manlock pressure to vary without affecting the man in the chamber.

If a two-gas atmosphere is utilized, the test subject will breathe down the oxygen partial pressure, until it reaches the desired set point. As this breathe down occurs, the system total pressure will drop. Nitrogen will be added by regulator R-4 to maintain the desired suit total pressure. When the pO_2 falls below the set point, the pO_2 meter contacts close, and SV-2 opens, admitting O_2 to the system. As the pO_2 rises, the meter contacts open, and SV-2 closes. Thus, pO_2 is maintained independent of the system total pressure.

Additional controls are provided to prevent system pressure, and pO_2 from dropping below minimum viability limits in the event of emergencies. A low limit switch is provided on the pressure control meter (measuring blower suction pressure) that will activate valve SV-1. This switch would be adjusted prior to the test to cut in at suit pressures of 0.5 to 1 psi below the lower nominal limit. Thus, if suit pressure should fall, for any reason such as a tear, umbilical rupture, etc. valve SV-1 would open admitting a high O_2 flow to the system. By the same token, an absolute pressure switch, APS-1, is used to actuate SV-1 if the ECS outlet pressure should ever fall below 3.5 psia. This is a last ditch control, and would insure a minimum ECS outlet pressure of 3.5 psia. To prevent choking the flow to the suits when this high flow is required, provisons are made to open both air flow control valves whenever SV-1

is activated. Included in this system is a latching relay with a manual reset. Thus, if an emergency occurs, both air flow control valves would open to their maximum extent and would remain open until manually reset. This provides a minimum resistance path for the emergency oxygen flow to the pressure suit.

An emergency oxygen cylinder is also provided. If the normal 0_2 cylinder and regulator, R-2, could not, for some reason, supply sufficient oxygen to the control valves SV-1, SV-2, and SV-3, the emergency oxygen cylinder would automatically cut in and supply this oxygen. In operation, regulator R-2 would be adjusted to deliver oxygen at 100 PSI, and regulator R-1 at slightly under 100 PSI, say 90 PSI. Since R-2 normally maintains the supply line at 100 PSI, R-1 would never open, and emergency 0_2 would not be used. Should the normal 0_2 cylinder be depleted, or if it cannot supply the required 0_2 flow, the line pressure would fall. At 90 PSI, regulator R-1 would open and admit emergency oxygen to the system.

During normal repressurization, the subject enters the manlock, connects to the manlock umbilical and the manlock pressure is raised to ambient. When the manlock pressure increases, DPS-1 closes when the manlock-to-blower suction pressure reaches 1.0 PSID. Valve SV-3 opens, repressurizing the system with oxygen. Thus, during repressurization, DPS-1 maintains the pressure suit at about 2.5 PSI above the manlock pressure.

During emergency repressurization, thus function is the same, except that since the man is in the chamber, connected to the chamber umbilical, DPS-3 controls the ECS and suit pressure. When the emergency repressurization control is actuated, DPS-3 is connected to SV-1. This provides a higher 0_2 flow rate to the system, preventing the chamber pressure from reaching and overtaking the suit pressure.

COMPONENT DESIGN AND ANALYSIS

Air Circulation Loop

Air Flow Components

The blower is a single stage, 3 lobe, rotary air compressor manufactured by M-D Blowers, Inc., Racine, Wisconsin. The blower, model number S57-3202.5C, comes complete with a 3 HP motor (440 V, 60 cycle, 3 phase) mounted on a base. The blower housing is anodized aluminum. Special seals are provided to minimize leakage to ambient, and all internal parts are compatible with a 100% O_2 environment.

The critical operating point for the blower occurs when the system pressure is lowest. When operating with 3.5 PSIA suits (the lowest suit pressure required), the blower must impart a 2 PSI rise to the ventilating airstream in order to circulate a maximum of 15 CFM through the pressure suit. Figure 3-A shows the pressures and ΔP's expected throughout the system when used with a 3.5 PSIA suit at 15 CFM. It was assumed that the ECS is placed close to the chamber penetration. This minimizes line losses when the test subject is connected to the 55' chamber umbilical. It also would help to balance the flow to the manlock, when the man is connected to the relatively short manlock umbilical. That is, the length of the lines from ECS to the man, including umbilicals, would be more nearly identical, for both conditions of man connected to the manlock umbilical, or man connected to the chamber umbilical.

Since the blower is capable of maintaining a pressure ratio of 1.8 from blower suction to blower discharge, a by-pass relief valve is required to limit the ΔP from ECS outlet to ECS inlet. That is, if blower suction pressure were 14.7 PSIA, blower discharge pressure could be as high as (1.8) (14.7) = 26.4 PSIA. If this pressure were applied to the outlet of

SYSTEM PRESSURES

SUIT PRESSURE = 3.5 PSIA
SUIT FLOW = 15 CFM

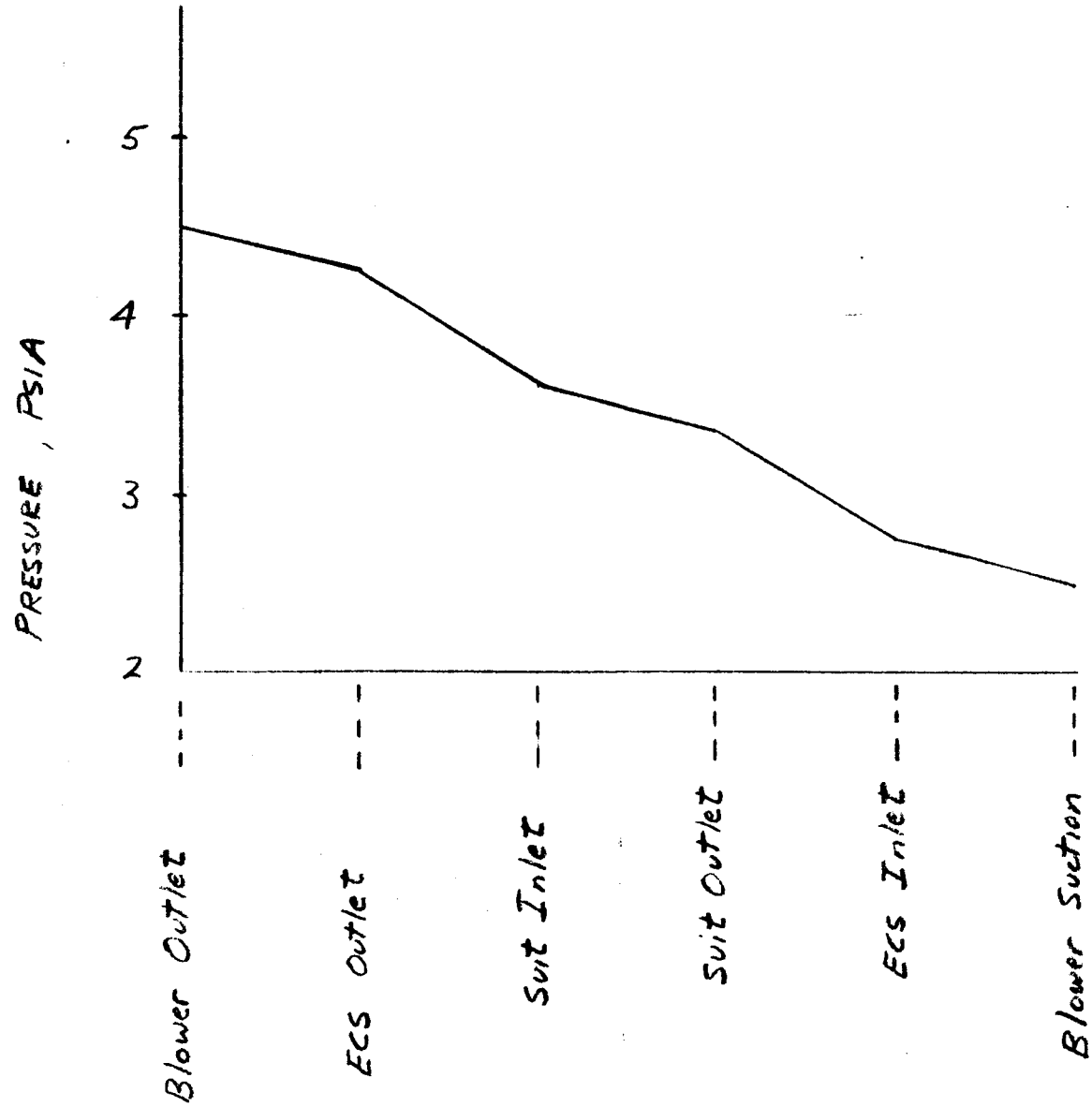


FIG 3A

the ECS, an extremely high ΔP would be experienced across the suit. Therefore, a by-pass relief valve is provided to limit the ΔP across the ECS, and thus, also, the suit, to normal values.

The performance requirements for the by-pass relief valve are:

Cracking pressure = 2.2 PSID

Full flow of 20 SCFM at 2.4 PSID and inlet pressure of 18.2 PSIA

Reseat pressure = 2.0 PSID

Media - 100% gaseous oxygen

The relief valve, therefore, limits the ΔP from ECS outlet to inlet to 2.0 to 2.4 PSI. This, then, is the pressure available to circulate the air flow through the flow control valves, umbilicals and pressure suit. The maximum airflow vs. the suit operating pressure can be approximated as follows:

Assume 1. Flow control valves are wide open, providing maximum air flow to the suit.

2. ΔP across umbilicals and pressure suits is 2.2 PSI

As seen in Figure 3-A, with a 3.5 PSI suit, a ΔP of 4.25 - 2.75 = 1.5 PSI produces an air flow of 15 CFM.

Also $\Delta P = K \frac{(\rho V^2)}{2g}$

where

ρ = air density

V = velocity

g = const.

K = const. (piping geometry)

let case 0 represent a 3.5 PSIA suit, and case 1 represent a suit at pressure P_1.

Then $\Delta P_o = K \frac{(\rho_o V_o^2)}{2g}$

and $\Delta P = K \frac{(\rho_1 V_1^2)}{2g}$

dividing $\frac{\Delta P_o}{\Delta P_1} = \frac{\rho_o V_o^2}{\rho_1 V_1^2}$

now $\rho \propto P$ (for same gas and temperature)

and $CFM = VA \propto V$ (A const.)

thus $\frac{\Delta P_o}{\Delta P_1} = \frac{P_o (CFM_o)^2}{P_1 (CFM_1)^2}$

for case 0, $\Delta P_o = 1.5$ PSI, $P_o = 3.5$ PSIA, CFM = 15

for case 1, $\Delta P_1 = 2.2$ PSI,

thus $CFM_1 = \frac{34}{\sqrt{P_1}}$

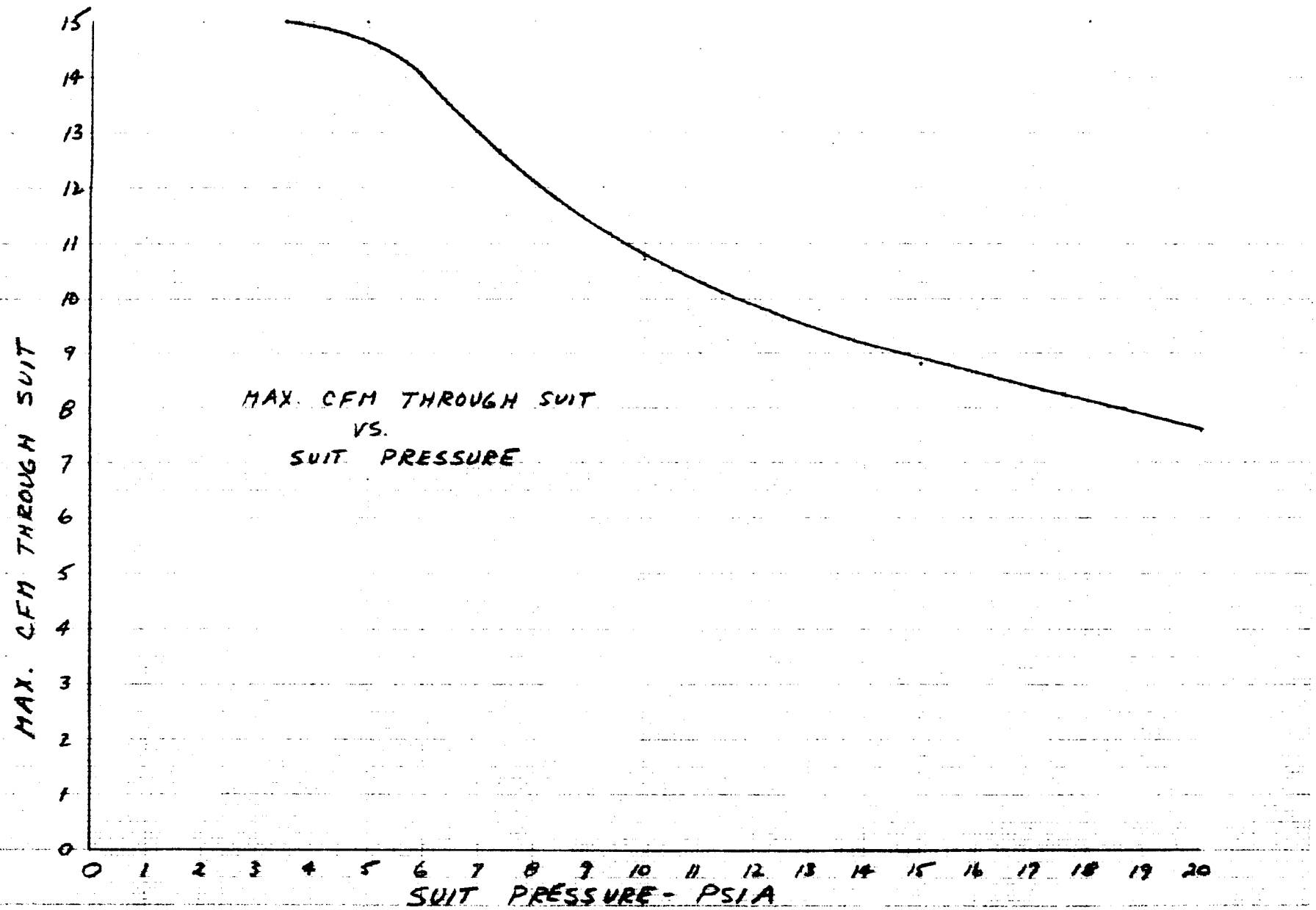
This equation is plotted in Figure 4-A. As seen, as suit pressures increase, the suit flow decreases.

The flow rate through the suit can be decreased by closing the suit airflow control valves. These are 1½" butterfly air valves, manufactured by the Barber-Colman Co., Rockford, Illinois. The valves are motor actuated, and the positioning and sychronizing circuits are designed to remotely position the two valves simultaneously. For any one set point on the control, both valves would be at the same position.

Providing two synchronized valves, one at ECS outlet, and one at ECS inlet provides for a stable suit pressure for any airflow. Referring to Figure 3-A, it can be seen that if only one valve were used, at ECS outlet, the suit pressure would drop as the airflow is decreased, because, with less airflow, the ΔP through the umbilicals and suit would decrease and approach the value of the blower suction pressure. Conversly, if one value were placed at the ECS inlet, the suit pressure would rise as the airflow is decreased.

As the valves close, restricting the suit airflow, a portion of the ECS air circulation is by-passed through the relief valve. Also, since the blower is essentially a constant CFM device, air flow will be by-passed

FIG 4A


MAX. CFM THROUGH SUIT
VS.
SUIT PRESSURE
MAX. CFM THROUGH SUIT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
SUIT PRESSURE - PSIA

through the relief valve whenever suit airflow is below 15 CFM.

A venturi flowmeter is provided at the ECS discharge to measure the suit airflow rate. The ΔP across the venturi will range from about 3 to 20 in - H_2O, depending on suit airflow and total pressure. The venturi after manufacture, should be calibrated for the range of flows and pressures required.

CO_2 Absorber Canister

The relatively short operating time of the ECS, for any one mission, does not warrant the use of regenerable adsorbents, such as molecular sieves. Rather, for this application, expendable absorbants for CO_2, which can be replaced after each test, result in minimum system complexity. Among the available absorbants, lithium hydroxide and "Baralyme" are the most useful because of their comparatively high absorption capacity for CO_2, and the availability of prior use experience for these materials.

Of the two, lithium hydroxide is the most efficient. However, lithium hydroxide has a disadvantage in that is produces, in handling and use, a fine powdery toxic dust. Canister design must necessarily be more complex, in order to prevent this dust from entering the air stream, and handling problems are most difficult. Baralyme, on the other hand, exhibits none of these problems, and thus was selected for use as the CO_2 absorbant in the ECS.

The amount of baralyme required was calculated as follows:

Maximum duration = 8 hours

Average metabolic rate = 800 BTU/HR.

O_2 consumption (assuming 1 liter of O_2 consumed will produce 4.83 Kcal metabolic heat)

$$= 800 \frac{\text{BTU}}{\text{HR.}} \times 0.252 \frac{\text{Kcal - hr.}}{\text{BTU}} \times \frac{1 \text{ liter}}{4.83 \text{ Kcal}} = 41.9 \frac{\text{liters}}{\text{hrs.}}$$

Assuming a respiratory quotient (R.Q.) of 0.82

CO_2 produced = (0.82) (41.9) = 34.4 liters/hr.

= 9.7 ft^3/8 hrs. (total)

since ρ CO_2 @ STP = 0.1225 lb/ft^3

wt. CO_2 produced = 1.2 lbs., total

Therefore, the baralyme must absorb 1.2 lbs. of CO_2. The theoretical absorbtion capacity of baralyme for CO_2 is 0.435 lb. CO_2/lb. baralyme. Assuming an absorption efficiency of 75% of theoretical capacity, the amount of baralyme required is:

$$\text{wt. baralyme} = \frac{1.2}{(0.435)\ (0.75)} = 3.7 \text{ lbs.}$$

The density of the loaded baralyme pellets is 0.0314 lb/in^3

$$\text{volume of baralyme req'd.} = \frac{3.7}{0.0314} = 118 \text{ in}^3$$

The canister is sized to accommodate a chemcial charge of 125 in^3. This allows 118 in^3 for the baralyme and 7 in^3 for the charcoal. When charging the canister, the charcoal, used to adsorb odors, should be dispersed throughout the baralyme.

The design of the CO_2 canister shown in Drawing 101D1340 is similar to one manufactured by G.E. for an emergency breathing system (Ref. 9). The canister consists of a plexiglas cylindrical outer shell and a stainless steel wire mesh screen inner shell concentric with the plexiglas. A stainless steel plate is butted against one end of the cylinder, while the other end is held against the inlet and outlet ports by six threaded rods and fasteners. When thus fitted, smaller diameter (approximately 1 1/4" dia.) wire mesh screen cylinders line up with the ports. These smaller cylinders

run the full length of the canister, and their axis is parallel to that of the larger screen and plexiglas cylinders. The baralyme CO_2 absorbant and activated charcoal are loaded between the 1 1/4" dia. wire screen cylinders and the larger diameter wire screen cylinder. A plate is inserted between the two smaller cylinders and extends to the circumference of the larger wire screen cylinder, thus cutting the canister in half.

In operation, the CO_2 laden air enters the canister into one of the 1 1/4" dia. wire screen cylinders. The air then flows through the screen mesh, and passes through the baralyme between the small cylinder and the larger screen cylinder. The air then passes through the larger diameter screen cylinder into the circumferential air space between this cylinder and the plexiglas. Passing halfway around the cylinder, the air next flows through larger diameter screening, through the baralyme, into the other 1 1/4" dia. screen mesh cylinder, and out of the canister.

This canister design has several desirable features. One, the plate between the two smaller screen cylinders prevents the air from passing directly from one to the other. This assures complete utilization of the baralyme absorbant, as the airflow is forced to flow equally through the entire chemical load. Second, the airflow through the chemical bed is directed perpendicularly to the longitudinal axis of the cylindrical canister. This presents the maximum flow area to the canister airstream. Velocity through the bed is thus lowered, giving a low pressure drop and higher retention time for the ventilating air. The canister design might be called an annular flow, two pass absorbant canister. Third, all materials used in the canister are noted for their resistance to corrosion. Thus, corrosion problems, which could occur due to the caustic nature of the absorbant and the fact that water is evolved as the CO_2 is absorbed, are minimized.

Heat Exchanger

The heat exchanger is housed in a six inch diameter shell, with conical diffuser inlet and exit. The heat exchanger coil is a finned tube type, (Ref. 10) manufactured by Rome-Turney Co., and is coiled around a four inch diameter baffle within the heat exchanger housing. In operation, the water-glycol coolant is pumped through the heat exchanger coil, and the air is cooled and excess water condensed as it passes over the finned tube. The condensed water drops down to the bottom of the heat exchanger where it collects in a trough, and ultimately flows, by gravity to the condensate collection reservoir. All parts of the heat exchanger, except the coil, are made of stainless steel, to minimize corrosion problems. The Rome-Turney Company coil is copper and the outside (air side) is coated with a solder flashing as a result of the manufacturing process. Drawing 113C8788 shows the heat exchanger configuration.

The heat exchanger was designed to provide cooling and dehumidifcation of the pressure suit ventilating air during all phases of operation. It contains a large enough safety factor in the desing to assure that the required heat rejection capacity is provided under all operating conditions. The calculations used in the design of the heat exchanger are as follows.

The maximum heat loads imposed on the heat exchanger occur when the suits are pressurized to 17.2 PSIA (maximum required), and the maximum reheater power is used (i.e., temperature of the air to the suits = 80°F). The heat loads during this case are:

Metabolic Heat Load - Sensible

$$Q_{ms} = \dot{w} C_p \Delta T$$

where Q_{ms} = metabolic sensible heat load, BTU/HR.

$\dot{w}$ = air flow through suit, lb_m/hr.

C_p = air specific heat, $\frac{BTU}{lbm-\ ^oF}$

ΔT = air temperature difference, suit inlet to suit outlet (T suit in - T suit out) ^oF

since T suit in = 80^oF, there is little or no capacity for the air to remove sensible metabolic heat, i.e., T suit out 80^oF

$\therefore Q_{ms} = 0$

Metabolic Heat Load - Latent

$$Q_{ml} = L \Delta m_{H_2O}$$

Where Q_{ml} = metabolic latent head load, BTU/HR.

L = latent heat of vaporization for water, BTU/lb_m

Δm_{H_2O} = the mass of water picked up by the air flow from suit inlet to suit outlet per hour, lb_m/hr.

now assume T air out of heat exchanger = 42^oF and the relative humidity is 90%

Then p H_2O suit inlet = $0.1183\ lb_f/in^2$, where p H_2O is the water vapor partial pressure.

Assume, for maximum latent cooling, the air leaving the suit is 80^oF, 75% saturated.

Then p H_2O suit outlet = 0.38 lb_f/in^2

Now Δ p H_2O across suit = 0.2617 lb_f/in^2

and Δ m H_2O = $\dfrac{(CFM)\ (60)\ (\Delta p\ H_2O)\ (144)\ (M)}{RT}$

where M = molecular weight, water vapor

R = gas constant ft - lb_f/lb_m - ^oR

T = gas temperature, ^oR

CFM = Ft^3/min. through suit = 8.3 max., at suit pressure of 17.2 PSIA (See Figure 3A).

$\therefore$ Δ m H_2O = 0.413 lb_m/hr.

and $Q_{ml, max.}$ = (1050) (.413) = 434 BTU/HR.

Baralyme Sensible Heat Load

Baralyme releases 330 BTU/HR. for every 1b. of CO_2 absorbed

Assuming a peak metabolic rate of 2000 BTU/HR.

CO_2 production, peak = 0.37 lb./hr.

Q_{bs} = (330) (0.37) = 122 BTU/HR.

Baralyme Latent Heat Load

Baralyme releases 0.75 1b of H_2O for every 1b. of CO_2 absorbed

Q_{bl} = (0.37) (0.75) (1050) = 319 BTU/HR.

Blower Heat Load

The temperature rise across the blower can be calculated from the following formula:

$$\frac{T\ out}{T\ in} = \left(\frac{P\ out}{P\ in}\right)^{\frac{n-1}{n}} \qquad \text{where } n = 1.3$$

where T out = temperature at blower discharge ^{o}R

T in = temperature at blower inlet ^{o}R

P out = pressure at blower discharge PSIA

P in = pressure at blower inlet PSIA

With a suit pressure of 17.2 PSI, the blower pressure rise will be about 3 PSI, or 15.7 at blower inlet and 18.7 at blower outlet.

Thus $T_{out} = T_{in} \left(\frac{18.7}{15.7}\right)^{\frac{1.3 - 1}{1.3}} = T_{in}\ (1.041)$

now $T_{in} = T_{suit\ out} + \Delta T_b$

where ΔT_b = temperature rise across the CO_2 canister

and $\Delta T_b = \frac{Q_{bs}}{\dot{\omega}\, c_p}$

where $\dot{\omega}$ = mass flow rate through canister, $lb_m/hr.$

and $\dot{\omega} = \rho \times CFM \times 60$

where ρ = density of air, lb_m/ft^3

since the blower is operating at a reduced pressure ratio, the CFM will be slightly higher compared to the 15 CFM produced at a pressure ratio of 1.8), on the order of 18 CFM.

Thus $\dot{\omega} = (0.0868)\ (18)\ (60) = 93.7\ lb_m/hr.$

and $\Delta T_b = \frac{122}{(93.7)\ (.219)} = 6^{o}F$

and $T_{in} = 80 + 6 = 86^{o}F = 546^{o}R$

thus $T_{out} = (546)\ (1.041) = 569^{o}R$

now $Q_b = \dot{\omega}\ c_p\ \Delta T = (93.7)\ (.219)\ (23) = 473$ BTU/HR.

Reheater

The heat input due to the reheater, Q_h, is

$Q_h = \dot{\omega} \; C_p \; \Delta T = (93.7)\ (.219)\ (80-42)$

$Q_h = 780$ BTU/HR.

The total maximum heat load on the ECS heat exchanger, therefore, is:

BTU/HR.

	SENSIBLE	LATENT	COMBINED LOAD
Metabolic	0	434	434
Baralyme	122	319	441
Blower	473	0	473
Reheater	780	0	780
Total	1375	753	2128

Another case may be of importance in the design of the heat exchanger. This occurs at the lowest suit pressures, 3.5 PSIA. While the total maximum heat loads are lower, the heat transfer coefficients, which depend on air density, are also lower, and this case may be the critical point for establishing the size of the heat exchanger.

The heat loads for this case are:

Metabolic Sensible Heat Load

Air flow through suit = 15 ft^3/min

oxygen density, ρ, @ 65°F = 0.0199 lb_m/ft^3

thus oxygen mass flow, $\dot{\omega}$ = (CFM) (60) (ρ) = 17.9 lb_m/hr.

$Q_{ms} = \dot{\omega}\ Cp\ \Delta T$ where ΔT = 38°F (T in = 42°F, T out = 80°F)

thus Q_{ms} = (17.9) (,219) (38) = 149 BTU/HR.

Metabolic Latent Heat Load

As in case 1 (17.2 PSIA suit), Δ p H_2O = 0.2617 lb_f/in^2

Thus Δ_m H_2O = 0.744 lb_m/hr

and Q_{ml} = (0.744) (1050) = 780 BTU/HR.

Baralyme Sensible Heat Load

Same as case 1, 122 BTU/HR.

Baralyme Latent Heat Load

Same as case 1, 319 BTU/HR.

Blower Heat Load

$$\frac{T\ out}{T\ in} = \frac{(P\ out)}{(P\ in)}^{\frac{n-1}{n}} \qquad \text{where } n = 1.3$$

with a 3.5 PSIA suit, P in = 2.5 PSIA and P out = 4.5 PSIA, thus

$$T\ out = T\ in \left(\frac{(4.5)}{(2.5)}\right)^{\frac{1.3-1}{1.3}} = T\ in\ (1.145)$$

now T in = T out suits + ΔT_b

and $\Delta T_b = \frac{Q_{bs}}{\dot{\omega} C_p} = \frac{122}{(17.9)\ (.219)} = 31^oF$

Thus T in = 80 + 31 = 111°F = 571°R

and T out = (571) (1.145) = 645°R

now $Q_b = \dot{\omega}\ C_p\ \Delta T$ = (17.9) (.219) (654-571)

Q_b = 325 BTU/HR.

Reheater

If the reheater were on, any heat input due to this component would be subtracted from the metabolic sensible heat removed from the suit. Thus assume Q_h = 0

The total heat load for case 2 (3.5 PSIA suit) is:

	SENSIBLE	LATENT	COMBINED LOAD
Metabolic	149	780	929
Baralyme	122	319	441
Blower	325	0	325
Total	596	1099	1695

The heat transfer coefficient, h, for the air side of the heat exchanger can now be estimated.

Case 1 (17.2 PSIA suit)

$$\text{Reynolds No., Rey} = \frac{\rho V 4 r_h}{\mu}$$

where ρ = air density (assume 100% O_2) lb_m/ft^3

V = air velocity ft/sec.

r_h = hydraulic radius, ft.

μ = air viscosity $lb_m/ft\text{-}sec$

and the properties are evaluated at the average heat exchanger temperature

$$T_{ave} = \frac{T \text{ in} + T \text{ out}}{2} = \frac{569 + 502}{2} = 535.5^{\circ}R$$

now $$\rho = \frac{PM \times 144}{RT} = \frac{(18.7)\ (32)\ (144)}{(1544)\ (535.5)} = 0.104\ lb_m/ft^3$$

and $$V = \frac{CFM}{60A}$$ where A = free flow area, $ft.^2$

from Ref. 10, σ = 0.538 = free flow area/frontal area

and frontal area = $\frac{\pi}{4}(6)^2 - \frac{\pi}{4}(4)^2 = 0.109\ ft^2$

$$\therefore \quad A = (0.538)\ (0.109) = 0.0586 \text{ ft}^2$$

$$\text{and} \quad V = \frac{18}{(60)\ (0.0586)} = 5.1 \text{ ft/sec.}$$

also from reference 10, 4 rh = 0.0154 ft.

$$\mu = 13.7 \times 10^{-6} \text{ lb}_m/\text{ft-sec.}$$

$$\text{and Rey} = \frac{(0.104)\ (5.1)\ (0.0154)}{(13.7 \times 10^{-6})} = 596$$

from ref. 10

$$\left(\frac{h}{G\ C_p}\right) (P_r)^{2/3} = 0.0155$$

where h = heat transfer coefficient, BTU/HR-ft^2-^{o}F

$G = \rho\ V\ (3600)$ lb$_m$/ft^2-hr.

$P_r = \frac{C_p \mu}{K} \times 3600$ where K = thermal conductivity BTU/HR-ft^2-^{o}F/ft.

$G = (0.104)\ (5.1)\ (3600) = 1910$ lb$_m$/ft^2-hr.

$K = 0.0235$ BTU/HR.-ft^2-^{o}F/ft.

$P_r = 0.71$, $P_r^{2/3} = 0.794$

$$\therefore \quad h = \frac{(0.0155)\ (1910)\ (.219)}{.794} = 8.2 \text{ BTU/HR-ft}^2\text{-}^o\text{F}$$

similarly, for case 2 (3.5 PSIA suit)

$h = 4.5$ BTU/HR.-ft^2-^{o}F

The above heat transfer coefficients are based on a dry airflow. Since a good portion of the heat load is latent, and condensation takes place in the heat exchanger, the heat transfer coefficients will be higher than the above calculations show. Therefore assume that -

for case 1 $h = 10$ BTU/HR-ft^2-^{o}F

for case 2 $h = 7$ BTU/HR-ft^2-^{o}F

Now, the h for the water-glycol coolant side of the heat exchanger can be determined.

Coolant properties

Fluid media - 40% glycol - 60% water

T inlet - 34^{o}F

$\dot{w}$ - 0.8 gallons/minute = 424 lb_m/hr.

ρ - 66.1 lb_m/ft^3

C_p - 0.81 BTU/lb_m-^{o}R

K - 0.252 BTU/HR.-ft^2-^{o}F/ft.

μ - 1.15×10^{-4} lb_f-sec/ft^2

$$Rey = \frac{\rho V D}{\mu}$$ where D is tube inside diameter, ft.

$$V = \frac{\dot{w}}{(3600)\ A}$$ where A is tube flow area = .000556 ft^2

$$V = \frac{424}{(3600)\ (66.1)\ (.000556)} = 3.2 \text{ ft/sec.}$$

$$Rey = \frac{(66.1)\ (3.2)\ (0.0266)}{(1.15 \times 10^{-4})\ (32.2)} = 1520$$

$$P_r = \frac{C_p\ \mu}{K} \times 3600 = \frac{(0.81)\ (1.15 \times 10^{-4})\ (32.2)\ (3600)}{0.252}$$

$$P_r = 42.8$$

The generalized formula for heat transfer in this case is:

$$\left(\frac{h}{CpG}\right)(P_r)^{2/3} = 1.62\left(\frac{L}{D}\right)^{-1/3}(Rey)^{-2/3}$$

assume $L = 19$ ft., since $D = 0.0266$ ft., $\frac{L}{D} = 715$

Thus $\left(\frac{h}{CpG}\right)(P_r)^{2/3} = 1.62\ (715)^{-1/3}\ (1520)^{-2/3} = 0.00138$

$$h = \frac{(0.00138)\ (0.81)\ 424}{(.000556)\ (42.8)}^{(2/3)} = 70\ \text{BTU/HR-ft}^2\text{-}^o\text{F}$$

The temperature rise of the coolant can also be determined

$$\Delta T = \frac{Q}{\dot{w} C_p}$$

for case 1 $\Delta T = \frac{2128}{(424)\ (.81)} = 6.2^o\text{F}$

The amount of heat exchanger tubing required can now be calculated

for case 1 (17.2 PSIA suit)

$$Q = UA\ (LMTD)$$

where $LMTD = \frac{(T\ air\ in - T\ coolant\ out) - (T\ air\ out - T\ coolant\ in)}{Ln\ \frac{(T\ air\ in - T\ coolant\ out)}{(T\ air\ out - T\ coolant\ in)}}$

$$LMTD = \frac{(109 - 40.2) - (42 - 34)}{Ln\ \frac{(109 - 40.2)}{(42 - 34)}} = 28.2^o\text{F}$$

Now $Q = UA\ (28.2) = 2128; \quad UA = 75.5$

and $\frac{1}{UA} = \frac{1}{h_{air}\ A_{air}} + \frac{1}{h_{coolant}\ A_{coolant}}$ (neglecting conduction through the tube, and using a fin effectiveness of 1). From data on the heat exchanger tubing

$A_{air} = 0.89\ L\ ft^2$ where L is length of tubing

$A_{coolant} = 0.0835\ L\ ft^2$

$$\frac{1}{75.5} = \frac{1}{(10)\ (.89)\ L} + \frac{1}{(70)\ (.0835)\ L}$$

and $L = 20.4$ ft.

similarly, for case 2 (3.5 PSIA suit)

$L = 11.3$ ft.

The heat exchanger, as designed, contairs19.5 ft. of Rome Turney finned tube. This is slightly short of the 20.5 ft. required in case 1. However, this does not significantly affect the performance of the heat exchanger. The air outlet temperature from the heat exchanger, during maximum heat loads with a 17.2 PSIA suit would rise slightly above the assumed value of 42^oF to about 43 or 44^oF. This is entirely acceptable. As can be seen from the results of the case 2 analysis (3.5 PSIA suit) at lower suit pressures, there is more than ample heat exchanger capacity to reject maximum heat loads. Thus, with lower suit pressures, the air temperature out of the heat exchanger would be slightly below the assumed value of 42^oF.

Condensate Tank

The condensate tank is sized to collect all water condensed in the heat exchanger over 8 hours of operation. The maximum condensate that will be collected over this period is:

Metabolic Latent Heat Load

Assume suit air flow = 15 CFM (maximum)

Assume air temperature out of suit = 80°F and relative humidity = 75%

Then, max. latent heat load = 0.744 lb_m/hr

(See heat exchanger calculations, p_____)

Baralyme Latent Heat Load

The CO_2 production, corresponding to the above metabolic rate of 929 BTU/HR. = 0.172 lb/hr.

Baralyme latent heat load = (0.172) (0.75) = 0.129 lb_m/hr.

The total maximum amount of water, therefore, required to be stored in the condensate tank is:

(8) (0.744 + 0.129) = 7 lbs. H_2O

The condensate tank shown in drawing 113C8795 is cylindrical in shape and is 4.5" in diameter by 14" long. This tank is capable of storing 8 lbs. of water, thus providing for a small margin over the 7 lbs. requirements. A sight glass is installed in one end of the tank to give a visual indication of the amount of water in the tank. Valves are provided to drain the tank, even during operation of the ECS, if required. The tank is constructed of stainless steel to minimize corrosion.

Reheater

The function of the reheater is to control the temperature of the air inlet to the pressure suit. This is accomplished by supplying heat energy, in controlled amounts, to the cool air leaving the heat exchanger. The construction of the reheater shown in drawing 113C8798 , is similar to the heat exchanger, except that, instead of finned coolant tubes, there is a finned tubular electrical heater utilized. By varying the current through the electrical heater, the heat input, and thus air outlet temperature can

be accurately controlled.

The maximum reheater energy required is 780 BTU/HR. (see heat exchanger calculations, P) or 230 watts. Now the heater element surface area is about 43 in^2, thus,

$$\frac{Q}{A} = \frac{230}{43} = 5.35 \text{ watts/in}^2$$

also the face velocity across the heater, V, $= \frac{CFM}{(60)\ A}$ ft/sec.

where A = free flow area = 0.0409 ft^2

thus $V = \frac{18}{(60)\ (.0409)} = 7.3$ ft/sec.

From vendor data, for a watt density of 5.4, and an air velocity of 7.3, the sheath temperature of the heater will be about 400°F, when the air temperature is 80°F. This is well below the maximum allowable sheath temperature of 750°F. Thus, the heater design is conservative, and capable of supplying the required heat energy to the air.

Coolant Loop

Refrigeration Unit and Coolant Tank

The refrigeration unit and coolant tank are of conventional design and manufactured by the Filtrine Manufacturing Company, Waldwick, New Jersey. The condensing unit utilizes a 3/4 H.P. compressor (115 V, 60 cycle, 1 phase), freon 12 as the refrigerant, and is air cooled. The evaporator coils are located within the coolant tank. The coolant tank is stainless steel construction, and has an 8 gallon capacity for the 40% glycol - 60% water solution. This capacity is adequate to supply a constant coolant outlet temperature under fluctuating loads, and prevent the compressor from

"short cycling" under minimum loads. The refrigeration unit and coolant tank comes complete with all controls to maintain a coolant outlet temperature of 33 $\pm 1.5^{o}$F.

Coolant Pump Requirements

The ECS coolant pump must supply a flow of 0.8 gallons per minute through the heat exchanger against a maximum back pressure of 15 PSI. The pump selected for this requirements is Eastern Industries, Inc. Model D-11. This pump, which includes a 1/8 H.P. 115 V, 60 cycle, 1 phase motor will produce a flow of 0.8 gpm against a head of 17 PSI. A throttling valve is provided in the coolant circuit to regulate the flow to the desired value.

The suit coolant pump must supply a flow of 0.5 gpm against a maximum back pressure of 30 PSI. The pump selected is Eastern Industries model 2F-34B. This pump meets these requirements exactly. The pump motor is a 1/3 H.P., 115 V, 60 cycle AC, 1 phase machine. Again, if the back pressure is less than 30 PSI, a throtling valve is provided to give the desired flow rate.

Refrigeration System Capacity Requirements

The heat load on the refrigeration unit is as follows:

ESC Heat Exchanger

The maximum load on the ECS exchanger is 2128 BTU/HR. (see heat exchanger calculations, P).

ESC Coolant Pump

$$\text{Pumping power required} = \frac{(\dot{w})(H)}{33{,}000} \quad \text{Horsepower}$$

where $\dot{w}$ = coolant flow rate, lbs./min.

H = head, ft.

now $\dot{w}$ = (gpm) (0.1337 ft^3/gal) (ρ)

where ρ = coolant density = 66.1 lb_m/ft^3

$\dot{w}$ = (0.8) (.1337) (66.1) = 7.1 lbs./min.

now 1 ft. head of coolant = $\frac{66.1}{144}$ = 0.46 PSI

$$H = \frac{17}{0.46} = 37 \text{ ft.}$$

and $$HP = \frac{(7.1)\ (37)}{33{,}000} = .008$$

Assuming all the pumping power goes into heat into the coolant

$$Q = \frac{(0.008)}{3.927 \times 10^{-4}} = 20 \text{ BTU/HR}$$

Suit Coolant Pump

Similarly, for the suit coolant pump

Q = 25 BTU/HR.

Metabolic Load

Under conditions of max. heat load on the ECS heat exchanger, the air ventilation circuit will remove 434 BTU/HR. from the man. This is included in the 2128 BTU/HR. total load on the heat exchanger. Assuming a total maximum metabolic rate of 2000 BTU/HR., the heat input to the suit coolant is:

2000 - 434 = 1566 BTU/HR.

Coolant Tank Jacket Losses

8 gallon capacity tank, dimensions 8" dia. x 3.0 ft. L, surface area = 10 ft^2

Find heat gain through jacket, Q, assume 1" fiberglas insulation around tank

$H_{air\ side}$ = 4 BTU/HR. - ft.^{2} - ^oF

h Coolant side = 40 BTU/HR. - ft.^{2} - ^oF

K fiberglass = 0.25 BTU/HR. -ft.^{2} -^oF/in.

$$\text{Then } \frac{1}{U} = \frac{1}{h_{\text{air side}}} + \frac{L}{K_{\text{fiberglas}}} + \frac{1}{h_{\text{glycol}}}$$

U = 0.233 BTU/HR.-ft^2-^oF

Assume facility ambient = 110^oF

glycol temperature = 32^oF

then Q = UA ΔT

Q = (.233) (10) (110-32) = 182 BTU/HR.

Total Heat Load on Refrigeration System

ECS heat exchanger		2128 BTU/HR.
ECS coolant pump		20
Suit coolant pump		25
Metabolic load (suit coolant)		1566
Coolant tank jacket losses		182
	TOTAL	3921 BTU/HR.

The condensing unit selected has a heat removal capacity of 5150 BTU/HR. with a suction temperature of 25^oF, and an ambient air temperature of 110^oF. This is ample capacity to handle the maximum heat load on the system, and would have good "pull down" characteristics.

Pressurization Control Subsystem

Oxygen Requirements

Oxygen must be supplied to the ECS on demand to fulfill the following requirements.

ECS Purge

Evacuate ECS lines and umbilicals, refill with 100% O_2

Assume ECS volume = 2.0 ft^3

Umbilical = 1.5 ft^3

Final pressure (at blower suction) = 15.7 PSIA

ft^3 (STP) O_2 required = $3.5 \times \frac{15.7}{14.7} = 3.75\ ft^3 \approx 4\ ft^3$

Suit Purge

Add 10 CFM O_2 for 1 minute to sweep out suit volume before closing faceplate.

ft^3 (STP) O_2 required = 10

Metabolic

Assume average metabolic rate of 1000 BTU/HR. for 8 hours.

O_2 consumption = $\frac{(1000)\ (0.252)\ (8)}{(4.83)\ (28.316)} = 14.75\ ft^3 \approx 15\ ft^3$

Leakage

Assume suit and umbilical leakage as 500 cc/min (STP) at 3.5 PSIA, 100% O_2 suit pressure

Then O_2 required = $\frac{(500)\ (60)\ (8)}{28{,}316} = 8.5\ ft^3$ (STP)

Recompression

Pressurization from 3.5 PSIA to 17.2 PSIA (suit pressure)

Assume suit volume = 1.0 ft^3

Then total volume = 1.0 + 3.5 (ECS and umbilical) = 4.5 ft^3

O_2 required = $\frac{(4.5)\ (17.2 - 3.5)}{14.7} = 4.2\ ft^3$

Emergency

In the event of an emergency, requiring a large O_2 flow to the suit (such as a suit tear), the emergency controls would supply a maximum of 10.24 CFM to the ECS.

Assume emergency duration = 5 minutes

O_2 required = (10.24) (5) = 51 ft^3

Total O_2 Required	ft^3
ECS purge	4.0
Suit purge	10.0
Metabolic	15.0
Leakage	8.5
Recompression	4.2
Emergency	51
TOTAL	92.7 ft^3 $\approx$ 93 ft^3

A standard oxygen cylinder contains 305 standard ft^3 of oxygen when full. Thus the normal O_2 supply cylinder should be at least 1/3 full before starting a test. Instrumentation is provided for reading O_2 quantity on the ECS control panel.

Oxygen Flow Requirements

Solenoid valves are required to control the inflow of oxygen to the system, to perform the functions listed above. Since these functions, i.e., metabolic O_2 make-up, suit purge, etc., require different amounts of oxygen per unit time, several solenoid valves are required, each providing a different O_2 flow rate.

The flow rate requirements are:

ECS Purge

The flow rate of O_2 when repressurizing the ECS is not critical.

Suit Purge

The flow rate required for suit purging must be fairly high, but is not critical. About 10 ft^3 of gas are required for purging. Thus a flow of 5 to 10 CFM should be sufficient, corresponding to times of 1 to 2 minutes for the purge cycle.

Metabolic and Leakage

Max. use rate = 30 + 8.5 = 38.5 ft^3/8 hours
(assuming 2000 BTU/HR)

Nominal use rate = 15 + 8.5 = 23.5 ft^3/8 hours
(assuming 1000 BTU/HR.)

Now assuming a control dead band of 20 mm Hg. (i.e., $\pm$10 mm Hg. variation beyond set point)

ft^3 O_2 added per valve opening = $V \frac{(20)}{(760)}$ ft^3

where V = system volume = 4.5 ft^3

ft^3 O_2 = 0.118 ft^3

Now, no. of valve opening per hour, max. = $\frac{38.5}{8\ (.118)} = 40$

and no. of valve openings per hour, nom. = 25

Thus the valve must open once every 1.5 minutes during maximum O_2 consumption.

Now let time of valve opening = 30 seconds

Then flow rate req'd. = $\frac{0.118}{0.5}$ = 0.235 CFM

flow rate $\approx$ 0.25 CFM

Thus, with this flow rate the valve will open for 30 seconds once every 1.5 minutes during maximum O_2 usage, and once every 2.4 minutes during nominal O_2 usage.

Recompression - Normal

The flow rate of O_2 required for normal repressurization of the manlock must be sufficient to keep the ECS and suit pressure higher than the manlock pressure. The rate of pressure increase of the manlock can be varied from 10 mm Hg/min to 478 mm Hg/min. To be compatible with these descent rates, the oxygen inflow rate must be sufficient to pressurize the ECS and suit at 478 mm Hg/min or greater.

$$O_2 \text{ flow rate req'd} = V \times \frac{478}{760}$$

where V - volume of ECS, umbilicals and suit - 4.5 ft^3

O_2 flow rate = 2.82 SCFM

Thus a flow rate of 3 SCFM would be sufficient to repressurize the ECS and suit systems.

Recompression - Emergency

The flow rate of O_2 required for emergency repressurization of the chamber must be sufficient to keep the ECS and manlock pressure higher than the chamber.

Assuming maximum chamber repressurization rate = 0.5 PSI/sec.

$$O_2 \text{ flow rate to ECS} = \frac{(0.5)}{(14.7)} \quad (V) \quad (60) \quad ft^3/min$$

where V = system volume, 4.5 ft^3

O_2 flow rate = 9.2 ft^3/min.

Therefore a flow of 10 CFM would be sufficient to assure a rapid repressurization capability for the suit.

Emergency

A high make-up O_2 flow is required in case of an emergency (suit tear, umbilical rupture, etc.)

Assume a 1/2" d tear in suit

Required

Sufficient O_2 flow to maintain a 3.5 PSIA pressure upstream of the tear.

Assume sonic orifice flow through tear

$$w = \frac{0.532 \; P_o \; A \; C_D}{\sqrt{T_o}} \quad \text{lb/sec} \qquad \text{(exact for air flow, but close for } O_2\text{)}$$

where w = O_2 flow, $lb_m/sec.$

P_o = upstream pressure, lb_f/in^2

A = orifice area, in^2

C_D = coefficient of discharge

T_o = upstream gas temp., ^oR

$$w = \frac{(0.532)\;(3.5)\;(\pi/4)\;(0.5)^2\;(.82)}{530} = .013 \; lb_m/sec.$$

w = 0.78 $lb_m/min.$

$$\text{Flow CFM (STP)} = \frac{0.78}{\rho} = \frac{0.78}{0.089} = 8.8 \text{ CFM}$$

Summary, Valve Requirements, O_2 inflow

Valve	CFM	Function
SV-1	10	Emergency repressurization, Emergency O_2 (suit tear, etc.), Suit Purge
SV-2	0.25	Normal O_2 make-up
SV-3	3	Normal repressurization, ECS purge

Thus, 3 valves can satisfy the flow requirements for the six functions. Since ECS purge flow rate is not critical, it is compatible with the flow required for normal repressurization.

The valves selected for use are Skinner solenoid valves, type V52 DA100. They have a 1/8" diameter orifice, which, at 100 PSI inlet pressure, can provide 15.8 SCFM flow rate. They are equipped with an integral flow metering needle valve which can be adjusted to provide any flow from 0 up to this value.

Vacuum Pump

The vacuum pump evacuates the ECS and umbilicals as part of the ECS purge cycle. It also has the function of depressurizing the ECS, umbilicals and suit during the manlock pumpdown. The capacity of the vacuum pump must be high enough to accomplish this pumpdown in a reasonable length of time. The capacity required is as follows:

Air Pumpdown

The manlock pumpdown rate (ascent rate) can be varied from 10 mm Hg/min to 815 mm Hg/min. The vacuum pump, in order to "keep up" with the manlock pumpdown, must then be capable of the same ascent rates. That is, at maximum change of pressure conditions; the vacuum pump must evacuate the ECS and suit from 16.2 PSI to 3.0 PSI in 0.835 minutes (equivalent to 816 mm Hg/min)

Thus assuming the pumping speed is independent of the ECS pressure

$$\frac{\log P_o - \log P_1}{t} = \frac{S}{2.303\ V}$$

where P_o = initial system pressure, PSIA

P_1 = final system pressure, PSIA

t = time, min.

V = system volume, ft^3

S = pumping speed, $ft^3/min.$

thus $$\frac{\log 16.2 - \log 3.0}{0.816} = \frac{S}{(2.303)\ (4.5)}$$

and $S = 9.1$ CFM

The actual CFM rating of the pump must be slightly higher than the 9.1 CFM given above, to account for the flow conductance through the lines and umbilicals. The pump selected for use with the ECS is a F. J. Stokes Co. Model 146-H, which has a nominal displacement of 23.5 CFM. Thus this pump is more than adequate to depressurize the ECS and suits at the maximum required rate. In operation, valve MV-4 would be adjusted so that the ECS and suit could be evacuated at a rate slightly higher than the maximum (815 mm Hg/min.) but low enough to prevent exceeding 0.5 PSI/sec. The control system (switch DPS-2 and SV-5) would then control ECS pressure, during manlock pumpdown, to 1.5 PSI above manlock ambient, for any manlock ascent rate between 10 and 816 mm Hg/sec.

ENVIRONMENTAL CONTROL SYSTEM DESIGN SPECIFICATION

1. SCOPE

This specification establishes the design requirements for an Environmental Control System (ECS) to be used in conjunction with the NASA-Langley Research Center (LRC) space environment simulation chamber. The following requirements are established to define a system which accomplishes all the life support functions necessary to maintain a suited man within the low vacuum environment of the LRC vacuum cylinder.

2. APPLICABLE DOCUMENTS

2.1 Government and Military Documents

The following documents in effect on the date of issuance of this specification form a part of this specification to the extent described herein.

Specifications

MIL-Q-5923	Quality Control Requirements, General
MIL-W-8160	Wiring, Guided Missile, Installation of

Standards

MIL-STD-130 B	Identification & Marking of Equipment
MS-33586	Metals, Definition of Dissimilar

2.2 Other Publications

The following documents, in effect on the date of issuance of this specification form a part of this specification to the extent defined herein.

Drawings

(Later)	Electrical Schematic, ECS Module
(Later)	Mechanical Schematic, ECS Module
201R803	Assembly, ECS Module

3. REQUIREMENTS

3.1 Description of the ECS

The environmental control system will be capable in normal operation of sustaining one suited subject within the LRC Vacuum Cylinder. The environmental control system, ECS, is defined as that equipment external to the Vacuum Cylinder necessary to sustain the viability of subjects wearing fully pressurized space suits. Included in this definition are all allied external interconnecting lines, penetration fittings or blanks, cabling, system instrumentation, control devices and consoles. All umbilicals, fittings, manifolds, cabling and instrumentation that are inside the vacuum cylinder are not considered a part of the ECS.

Except for the above mentioned cabling, interconnecting lines, etc., each of the ECS shall be designed as a self-contained module and shall be located external to the vacuum cylinder with external distribution piping to connect every chamber penetration to the ECS module. Each of the two independent ECS shall service one active chamber penetration. The ECS will operate as a closed loop system in which gases are recirculated between the man and the ECS module in order to permit accurate control of environmental parameters and to provide the capability for obtaining viability test data.

The ECS shall perform the following basic life support functions:

a. Ventilating/Breathing Oxygen Circulation
b. Sensible/Latent Heat (Moisture) Removal
c. CO_2 Removal
d. Total Pressure Regulation
e. Monitoring/Control Instrumentation

Drawing (Later) illustrates the sequence these functions shall follow along the main ventilating flow path.

3.2 General Requirements

3.2.1 Materials

3.2.1.1 Protective Treatment

When materials are used in the construction of the ECS that are subject to deterioration when exposed to climatic and internal environmental conditions likely to occur during service usage, they shall be protected against such deterioration in a manner that will in no way prevent compliance with the performance requirements of this specification. The use of any protective coating that will crack, chip or scale with age or extremes of climatic or internal environmental conditions shall be avoided

3.2.1.2 Dissimilar Metals

Insofar as practical dissimilar metals in contact with each other shall be avoided. However, metal plating or metal spraying of dissimilar base materials to provide similar or suitable abutting surfaces shall be permitted. The use of dissimilar metals separated by suitable insulating materials shall be permitted. Dissimilar metals are defined in MS-33586.

3.2.1.3 Acceptable Materials of Construction

The ECS shall be fabricated from materials listed herein which are acceptable for use in a low pressure gaseous oxygen atmosphere. Materials of construction which are not listed herein should be used only after a thorough investigation is made with regard to their acceptability for use in a life supporting gaseous oxygen atmosphere. Exceptions shall be allowed for materials which shall be used to construct those portions of the ECS equipment not in direct contact with the oxygen atmosphere.

3.2.1.3.1 Acceptable Alloys

a. Stainless Steel Alloys (300 series), (Passivated): 301, 302, 304, 305, 310, 321, 347, 348, 304L, 316L

b. Aluminum and Aluminum Base Alloys: 1100, 3003, 6061, 6951, 2014, 2214, (EMS 410) 2219, 5052, 5054, 5083, 5086, 5154

c. Nickel and Nickel Base Alloys: Monel, K Monel, Inconel, Inconel X, Inconel 718, Waspoloy, M252, Rene 41.

d. Copper and Copper Base Alloys: OFHC copper, Beryllium-copper alloys, 70-30 brass, nonleaded tin bronzes.

e. Precipitation Hardening Alloys (Passivated): 17-7PH, 174PH, A286, AM350, AM355, PH15-7 Mo.

f. Stainless Steel Alloys (400 series) (Passivated): 410, 420, 422, 440A, 440C

g. Cobalt Base Alloys: Haynes 25, Elgiloy, Cobenium

h. Steels (Plated): 1010, 1015, 1020, 1025, 4130, 4340.

3.2.1.3.2 Acceptable Non-Metallic Materials

The physical properties considered in the selection of acceptable materials shall include odor, toxicity, oxidation resistance, and fire resistance.

3.2.1.3.2.1 Acceptable Lubricants

a. G-300 Silicone Grease (250°F)

b. Versilube F50 Oil (250°F) (General Electric Co.)

c. ETR Grease B (250°F) (Shell Oil Co.)

d. ETR Grease H (250°F) (Shell Oil Co.)

* e. Fluorolube Grease Type "LG" (250°F) (Hooker Chemical Co.)

* f. Fluorolube FS Oil (250°F) (Esso)

g. Andok C Lubricant (200°F) (Esso)

h. Electrofilm 66 C (250°F) (Electrofilm Corp.)

i. Molykote (250°F) (Alpha Corp.)

j. Everlube (250°F) (Everlube Corp.)

k. Oxylube 702 (250°F) (Drilube Corp.)

* These materials shall not be used in conjunction with Aluminum and Aluminum Base alloys.

3.2.1.3.2.2 Acceptable Elastomers

a. Neoprene (250°F), MIL-R-6855, Class II

b. Buna N (160°F), MIL-P-5315 (Parker Compound #1011-10)

c. Buna N (160°F), MIL-P-5215 (Compound #457,) (Plastics and Rubber Co.)

d. Silicone (250°F), AMS 3345 Fully Cured

e. Silicone (360°F), Silastic S-2007 (Dow Corning)

f. Silicone (160°F), Compound #9711 (Dow Corning)

g. Polyurethane (160°F), Stafoam U543 (Dayton Rubber Co.)

h. Viton A (160°F), (E. I. DuPont)

i. Natural Rubber, Compound No. SR 221-40 (Stillman Rubber)

j. Natural Rubber, Compound No. SR 222-60 (Stillman Rubber)

3.2.1.3.2.3 Acceptable Thermoplastic Materials

a. Acrylic (250°F), MIL-P-8184 (Plexiglas 55, AS Cast)

b. Acrylic (160°F), MIL-P-5425 (Plexiglas II, AS Cast)

c. Acrylic (160°F), plexiglas No. 2072 (Rohm & Haas Co.)

d. Irradiated Polyethylene (250°F) Type RRT (Raytherm Corp.)

e. Nylon 101 (250°F), (E.I. Du Pont Co.)

f. Kel F Plastic (160°F) (3-M Co.)

g. Teflon (250°F), (E.I. DuPont Co.)

3.2.1.3.2.4 Acceptable Thermoset Plastics

a. Epoxy and Fiberglas (250°F), Coast F-150-14 (Coast Mfg.)

b. Polyester and Fiberglas (250°F), Coast F141 (Coast Mfg. Co.)

c. Phenolic and Fiberglas (250°F), Coast F120 (Coast Mfg. Co.)

d. Epoxylite No. 801 (300°F), (Epoxylite Corp.)

3.2.1.3.2.5 Acceptable Paint, Finishes, Coatings

a. Ajax Modified Silicone Insulating Varnish V61V25, (250°F), (Sherwin-Williams Paint Co.)

b. Silicone Varnish DC 997 (300°F), (Dow Corning)

c. Epoxy Cati-coat F55FP7 (207970-207990) (300°F), (Sherwin-Williams Paint Co.)

3.2.1.3.2.6 Acceptable Adhesives and Cements

a. Epoxy-Amine, (160°F), C-2 with Activator "A" Cured (Armstrong)

b. Epoxy Amine (160°F), A-2 with Activator "E", cured 1 hour at 200 F. (Armstrong)

c. Epoxy Amine (250°F), EC-4169 Epoxy EC-1470 Amine, heat cured (3M Co.)

d. Epoxy-Polyamid (250°F), Epoxy 828 (Shell Chemical, Versamid 125 (General Mills) (70% - 30%), cured 1 hour at 200°F

e. Neoprene-phenolic (250°F), EC-847 (3M Co.)

f. Neoprene (250°F), EC 870 (3M Co.)

g. Silicone (250°F), A4000 with XY-27 Catalyst (Dow Corning)

3.2.1.3.2.7 Acceptable Sealants

a. Silicone Primer EC-1694 (250°F), (3M Co.)

b. Silicone Encapsulating Compound EC-1663 (250°F) (3M Co.)

c. Silicone RTV 90 Sealant (400°F) (General Electric Co.)

d. Silicone PR 1910-8 RTV Sealant (400°F) (Products Research Co.)

e. Silicone RTV-Q-3-0121 Sealant (250°F) (Dow Corning)

f. Silicone RTV-731 Sealant (250°F) (Dow Corning)

3.2.2 Selection of Specifications and Standards

Specifications and standards for necessary commodities and services herein shall be selected in accordance with ANA Bulletin 143, except as provided in paragraphs 3.2.2.1 and 3.2.2.2.

3.2.2.1 Standard Parts

MS and AN standard parts shall be used except as noted in paragraph 3.2.2.2. Standard parts shall be identified by their MS or AN part number.

3.2.2.2 Commercial Parts

Commercial parts having suitable properties may be used where no suitable standard parts are available. In any case, commercial utility parts such as screws, bolts, nuts and cotter pins having suitable properties may be used provided:

a) They can be replaced by the standard parts (MS or AN) without alteration.

b) The corresponding standard part numbers are referenced in the parts list, and, if practical, on the contractor's drawing.

3.2.3 Wiring

Electrical wiring shall be in accordance with the requirements of specification MIL-W-8160D

3.2.4 Identification and Marking

Identification and marking of the environmental control system and its components shall be in accordance with standard MIL-STD-130B.

3.2.5 Operation

The ECS system shall have the capability of continuous operation for periods up to eight hours.

3.3 Design and Construction

3.3.1 Structural Configuration

The design configuration of the environmental control system shall be in conformance with G.E. drawing 201R803 "Environmental Control System Module Assembly", and drawing (later) "Mechanical Schematic, ECS Module"

3.3.2 Electrical Configuration shall conform to the requirements of drawing (later) "Electrical Schematic".

3.3.3 Structural Integrity

All ECS oxygen circuitry, accessories, piping, etc. shall be structurally designed to withstand a 15 PSI external-to-internal pressure differential with the lower pressure on the internal side. The system shall be capable of withstanding 5 PSI differential in the opposite direction as well (i.e., 20 PSIA internal pressure and 15 PSIA external ambient pressure).

3.3.4 Leak Tightness

The entire ECS installation shall be leak tight to the extent that inward leakage of air shall not increase the ECS internal total pressure by more than 2 mm Hg per day when the ECS internal pressure is 3.5 psia and the ambient pressure is 14.7 PSIA.

3.3.5 Design Life

The ECS equipment shall be designed to have an operating life of twenty years. Only normal maintenance and minor parts replacement should be required during this period.

3.4 Performance

3.4.1 External Environments

The ECS shall be capable of operating satisfactorily when it is exposed to the following extremes of external environment and is properly installed as a supporting system to a space environmental simulation chamber.

3.4.1.1 Temperature

The ECS shall be capable of meeting all of internal environment control functions specified in paragraph 3.4.2 when it is operating in an ambient temperature which ranges between +40°F and +110°F.

3.4.1.2 Humidity

The ECS shall be capable of satisfactory operation (defined as meeting all the requirements of paragraph 3.4.2) when it is exposed to ambient humidities over a range from 0 to 100%.

3.4.1.3 Altitude

Variations in barometric pressure normally encountered between sea level and 5000 feet above sea level shall not prevent the ECS from performing satisfactorily.

3.4.1.4 External Dynamic Environments

The ECS packaging component configurations and supporting structure shall be capable of withstanding the rigors associated with normal handling procedures during transportation, installation and routine operation and maintenance.

3.4.2 Internal (Suit) Environmental Control Functions

The ECS shall perform the following environmental control (life support) functions:

3.4.2.1 Ventilating Atmosphere Circulation

The ECS module shall be capable of delivering at its discharge port up to 15 CFM of atmosphere at a temperature of 50°F against a back pressure of 2.0 PSIG when operating in conjunction with suit pressures ranging between 3.5 and 17.5 PSIA.

A by-pass circuit within the ECS module shall give the capability for varying the ventilating delivery rate to the suits. The by-pass shall be capable of automatically limiting the pressure drop across the suit/umbilical circuits between 2 to 2.4 PSI thru the use of a relief valve. The relief valve also serves as a by-pass relief valve for the blower, preventing possible damage to the blower by always allowing air to circulate thru the system.

3.4.2.2 Pressure Regulation

Pressure regulation equipment for operation during both normal and emergency conditions (emergency chamber repressurization) shall be provided as described below. The capability for purging the system of undesired gases prior to operation shall be provided.

3.4.2.2.1 Pressure Regulation During Normal Operation

During normal operation the pressure regulation apparatus shall give the capability for controlling the system total pressure at blower suction to any given setting between 2.5 and 16.0 PSIA with a $\pm$ 0.2 PSIA tolerance. A demand make-up type absolute pressure regulator shall be used. Make-up nitrogen shall be supplied from a high pressure (2000 PSIA) cylinder. O_2 partial pressure shall be maintained by a solenoid valve pivoted by a control meter which in turn is driven by the system O_2 sensor. Make-up oxygen shall be supplied from high pressure (2000 PSIG) oxygen cylinders and shall be 100% aviator's breathing oxygen or equivalent.

This pressure regulation subsystem shall be capable of supplying oxygen to the system at flow rates up to 1.3 lb/hr. (.25 CFM) as make-up for metabolic consumption and leakage.

3.4.2.2.2 Pressure Regulation During Emergency Oxygen Make-Up

The ECS shall be provided with an emergency oxygen make-up circuit which is capable of providing make-up oxygen at a 10.25 SCFM rate which shall be sufficient to maintain suit pressure above chamber pressure during emergency chamber repressurization. The emergency make-up circuit must be capable of performing the above task under the extreme flow conditions which result from the occurence of a gross suit tear or umbilical rupture in one suit circuit. The emergency make-up circuit shall prevent the pressure in the remaining intact suits from dropping below 3.5 PSIA in the event of a tear or rupture in the system of up to 0.5 inches in diameter.

The emergency make-up circuit shall allow the entire ECS to be pressurized to 1 PSI higher than the ambient at blower suction in order to facilitate the locating of leak sources during pretest check outs. The emergency make-up circuit shall have high pressure storage cylinders which are separate from the normal make-up supply.

3.4.2.2.3 Purging of ECS

The ECS shall have the capability for purging prior to its operation. Purging will be accomplished by evacuating the entire system internal volume to a pressure below 1 mm Hg absolute by means of an integral vacuum pump. Subsequent to evacuation the system shall be repressurized to normal operating pressure with 100% oxygen by means of the normal oxygen make-up circuit.

3.4.2.2.4 Purging of Suits

The ECS shall have the capability for purging the suits prior to its operation. Purging will be accomplished by flushing the entire system internal volume with 100% oxygen at 1.5 PSI above airlock pressure.

3.4.2.3 Temperature Control

The system temperature control apparatus shall maintain the ventilating flow from any of the ECS outlets at various temperatures between 50°F and 80°F within a tolerance of ± 2°F for any given setting. The ECS shall be capable of supplying up to 45 lb/hr to subject at the above conditions. The temperature shall be independently controlled for each penetration.

3.4.2.3.1 Liquid Cooling

This ECS module shall be capable of supplying at its discharge part a 40% glycol - 60% water solution at a rate of up to 0.5 GPM against a back pressure of 30 PSI at a temperature of 50°F to 80°F. In addition the ECS unit shall have the capability for supplying coolant to the breathing room, where the sensible heat shall be removed from the suits (for liquid cooled suits only).

3.4.2.4 Humidity Control

The humidity control apparatus to be located within the ECS module shall maintain the specific humidity of the atmosphere between 4 and 8 mm Hg measured at any of the ECS penetration outlets. Water removal capability shall equal or exceed the net rate of 0.875 lbs. per hr. Provisions shall be made for the periodic removal of accumulated excess moisture from the system without interference with the operation of the ECS. (The ECS shall have the capability for continuous operation for periods up to eight hours).

3.4.2.6 Odor Removal

A means shall be provided to remove noxious odors from the system. The odor removal absorbent/adsorbent shall be mixed with the CO_2 absorbent in the suitable proportions.

3.4.3 Monitoring and Control Instrumentation

Critical system parameters shall be monitored and displayed remotely and are not considered a part of the ECS (Refer to SVS 7435). In addition, the following monitoring instruments shall be a part of the ECS as well.

3.4.3.1 Coolant Pump Flow Rate

The total flow rate from the coolant circuit to the suits shall be measured. The ECS shall have the capability for measuring the coolant flow rate to the suits in the pre-breathing room. The design flow rates are 0.5 GPM at 30 PSI. The flowmeter read-out shall have a 0 to 1 GPM range with an overall accuracy of $\pm$ 2% of maximum flow from 10 to 100% of full flow. Coolant flow rate (design rate of 0.8 GPM) to the heat exchanger (humidity control) shall be measured at the systems control console.

3.4.3.2 Analyzer Pump Flow Rate

The flow rate to the analyzers shall be measured. The design flow is 2 to 3 CFH. The flowmeter read-out shall have a 0 to 5 CFH range with an overall accuracy of $\pm$ 2% of maximum flow from 10 to 100% of full flow.

3.4.3.3 Oxygen Partial Pressure

The oxygen partial pressure in the system shall be measured and displayed on the ECS. An output signal suitable for a recorder input shall also be provided. Read out full scale range shall be 0-1200 mm Hg. A suppressed scale range of 0-300 mm Hg shall also be provided. Overall accuracy is $\pm$ 2%.

3.4.3.4 CO_2 Partial Pressure

The system CO_2 partial pressure shall be measured and displayed on the ECS. An output signal suitable for a recorder input shall also be provided. Full scale range of read-out shall be 0-20 mm Hg with an overall accuracy of $\pm$ 2%.

4.1 General

The components for the ECS shall meet the environmental requirements of this specification and the detail requirements in the applicable individual component designs.

4.2 Acceptance Testing

The entire ECS installation shall be tested in accordance with the procedures specified in the ECS Acceptance Plan.

5.0 ACCEPTANCE TEST PLAN FOR ENVIRONMENTAL CONTROL SYSTEM AND RESCUE ENVIRONMENTAL CONTROL SYSTEM

5.1 General

The vendor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the vendor may utilize his own or any other inspection facilities and services acceptable to the NASA-Langley Research Center (LRC). LRC reserves the right to witness any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

5.2 Test Program

The test program shall consist of sufficient tests to exhibit and insure overall system performance and reliability.

5.2.1 Classification of Tests

The systems shall be subjected to, and shall pass, the following test. Specific test plans, procedures and test results shall be submitted to LRC per the requirements of this specification.

5.2.1.1 Acceptance Tests

These tests are performed to assure that the materials, workmanship and performance of systems to be subjected to qualification tests or programmed for delivery to LRC are not faulty and that these assemblies have been manufactured to approved drawings and specifications.

5.2.2 Criteria for Failure

Deterioration or change in performance of any components which would in any manner prevent the equipment from meeting functional, maintenance and service requirements during service life, shall provide reason to consider the equipment as having failed to comply with the condition of the

test to which it was subjected.

5.3 Test Procedures

5.3.1 Test Quantities

The quantities of assemblies required for test are as follows:

5.3.1.1 Acceptance Tests

These tests shall be performed on all ECS and RECS scheduled for delivery.

5.3.2 Test Conditions

Unless otherwise specified, tests shall be conducted under the following ambient conditions:

a.	Temperature	Room temp. ambient (77 $\pm$18^{o}F)
b.	Relative Humidity	90% maximum
c.	Barometric Pressure	30 $\pm$2 inches of mercury

5.3.3 Measurements and Tolerances

5.3.3.1 Measurements

All pertinent signal and environmental inputs to the unit under test and all pertinent performance parameters shall be measured and recorded during all applicable tests. To the maximum extent possible, measurements shall be made in terms of standard units rather than arbitrary dial, indicator, or control settings.

5.3.3.2 Tolerances

5.3.3.2.1 Test Conditions

Unless otherwise specified, the maximum tolerances on test conditions shall not exceed the following:

a. Temperature ±2.0°C (±3.6°F)

b. Humidity +5 -0% (relative)

c. Pressure 1%

5.3.3.2.2 Tolerance Ratio

Whenever possible, a ratio of not less than 10 to 1 shall be maintained between the tolerance of the measured parameter and the tolerance of the measurement. The tolerance of the measurement shall include basic instrument accuracy and instrument-use errors such as resolution, repeatability and parallel.

5.3.3.2.3 Calibration

All test instruments shall be under the control of a calibration plan. The plan shall specify the frequency of calibration, accuracy of the calibration standards, and maintenance of calibration records. The calibration records shall be available for LRC inspection at any time.

5.4 Test Documentation

5.4.1 Performance Records

Records shall be made of all data necessary to determine compliance with this specification. This data shall provide criteria for checking satisfactory performance of the unit during testing. Test data shall be recorded before, during, and after each test as specified herein. The data shall include, but not be limited to, the following:

a. Data of Test

b. Test Program

c. Type of Test

d. Name, drawing number, serial number, and applicable equipment specification of the unit under test.

e. Test specification and applicable paragraphs.

f. Identification of each parameter measured, specification limits on the parameter, and actual parameter measurement of readings.

g. Name and location of manufacturer of unit under test.

h. Name and location of testing agency.

i. Name of individual conducting test and names of any Engineering, Quality Control, or customer witnesses.

j. Operating time during test including number of operating cycles.

k. Interruptions and causes.

l. Failure report numbers on each failure report written.

m. List of test instruments and equipment including manufacturers' names, model numbers, and identification serial numbers.

n. Calibration data including next calibration date and accuracy of equipment.

o. Record of visual examination performed before, during, and after tests.

p. Copies of all applicable vendor certified data.

5.4.2 Test Data Reports

Test reports, providing the data required by Paragraph 4.1, shall be submitted to LRC.

5.4.3 Failure Reporting

All failures as defined in Paragraph 2.2 shall be reported on a standard form in accordance with the requirement of LRC.

5.4.4 Failure Analysis Reporting

When required, failure analysis shall be performed in accordance with LRC direction.

5.4.5 Failures

5.4.5.1 Test Failures

Testing shall be suspended, and the failure shall be reported immediately to the responsible LRC Personnel. The determination whether to repair and retest or reject shall be at the discretion of the responsible LRC Personnel.

5.4.5.2 Acceptance Test Failures

Units under test, in which failures are detected during individual tests, shall be rejected. A failure report, shall be submitted. Testing of other units in the lot may continue. Rejected units shall be stored in a bonded storage area for inspection by an LRC Representative.

5.5 Acceptance Tests

5.5.1 System Examination

Each system shall be examined to determine compliance with applicable drawings per section 2.2 of the ECS or RECS Specification for physical dimensions, mounting provisions, and workmanship.

Both the ECS and RECS shall be referred to as the ECS in remainder of this document. Separate reference to the RECS shall be made only in those cases where design differences dictate the necessity.

5.5.2 Assembly Acceptance Test

Each assembly shall be tested to and pass the following acceptance tests prior to shipment to LRC.

5.5.2.1 Component Acceptance Test

Each component of the system shall have received an acceptance test prior to final installation in the assembly. The acceptance test shall consist of a performance test to prove proper operation of the component. In addition, a proof and leakage test shall be performed on all components located in the oxygen and nitrogen circuits.

5.5.2.2 Operation Assurance (O.A.) Test

An ECS O.A. test will be conducted at the assembly facility prior to shipment to LRC. This evaluation will verify that the ECS meets and to what extent exceeds the design specifications. The O.A. test plan shall be generated by the vendor and approved by LRC.

5.5.3 Quality Assurance (Q.A.) Test

As part of the acceptance tests, the following Q.A. tests shall be successfully completed at LRC.

5.5.3.1 Instrumentation

All ECS instrumentation shall be certified by the vendor for accuracy and calibration, (procedures to be supplied by the vendor). A nominal instrumentation checkout shall be made at the installation site to assure the instrumentation operational performance after shipping, handling, etc.

5.5.3.2 Proof Pressure

With the ECS stabilized at room temperature the following pressure shall be applied for a period of two (2) minutes.

Circuit	Pressure
Atmosphere Ventilating Circuit	30 PSIG
Heat Exchange Coolant Loop	100 PSIG

At the conclusion of the proof pressure test the assembly shall be examined for evidence of structural failure.

5.5.3.3 External Leakage

The systems shall be checked for external leakage as follows.

5.5.3.3.1 Atmosphere Ventilating Circuit

The atmosphere ventilating circuit shall be checked for external leakage by capping the outlet and

a) In the case of the ECS run the ventilating circuit at 20 PSIA with the ambient at 14.7 PSIA.

b) In the case of RECS evacuate the ventilating circuit to 30 PSIA with an ambient of 14.7 PSIA.

Leakage shall not exceed that specified in Paragraph 3.3.4 of SVS 7431 and 7432.

5.5.3.4 Checkout Instrumentation

Any equipment required in addition to the ECS equipment required for the ECS evaluation shall be calibrated in a similar manner as described below:

5.5.3.4.1 All flowmeters will have certified calibrations.

5.5.3.4.2 All pressure gages will be of a laboratory type and will be calibrated prior to use.

5.5.3.4.3 All temperature sensors shall have their accuracy checked prior to use.

5.5.4 Functional Test

5.5.4.1 Procedure

Men will not be sustained by the ECS during the system functional test due to the inherent variation of man's consumption of oxygen and production of carbon dioxide, latent heat (Water vapor) and sensible heat . Instead, in order to acquire accurate test data, a man simulator will be connected to the system which removes oxygen, introduces carbon dioxide, and latent and

sensible heat into the system at known accurately metered rates. Also the man simulator will duplicate the umbilical and suit pressure drop characteristics. A man simulator flow diagram is shown in Figure 1.

5.5.4.2 Instrumentation

Instrumentation in addition to that of the ECS and RECS is required to measure the following parameters;

5.5.4.2.1 Oxygen removal rate from ECS by man simulator.

5.5.4.2.2 Nitrogen (rate of addition to total quantity) added to system by man simulator.

5.5.4.2.3 Carbon dioxide (rate of addition total quantity) added to system by man simulator.

5.5.4.2.4 Water vapor added to system by man simulator.

5.5.4.2.5 Sensible heat added to system by man simulator.

5.5.4.2.6 Pressure drop through man simulator.

5.5.4.2.7 Pressure rise across blower.

5.5.4.2.8 Temperature of coolant inlet to heat exchanger.

5.5.4.2.9 Temperature of coolant outlet from heat exchanger.

5.5.4.2.10 Temperature of flow into heat exchanger.

5.5.4.2.11 Temperature of flow from heat exchanger.

5.5.4.2.12 Temperature of flow from reheater.

5.5.4.2.13 Water vapor content in atmosphere flow from heat exchanger.

5.5.4.2.14 Carbon monoxide content in atmosphere flow.

5.5.4.3 Man Simulator

Figure 1 shows a flow diagram of a simulator to duplicate the average metabolic input/outputs of one or two men as required, as well to duplicate the flow resistances of an umbilical and pressure suit.

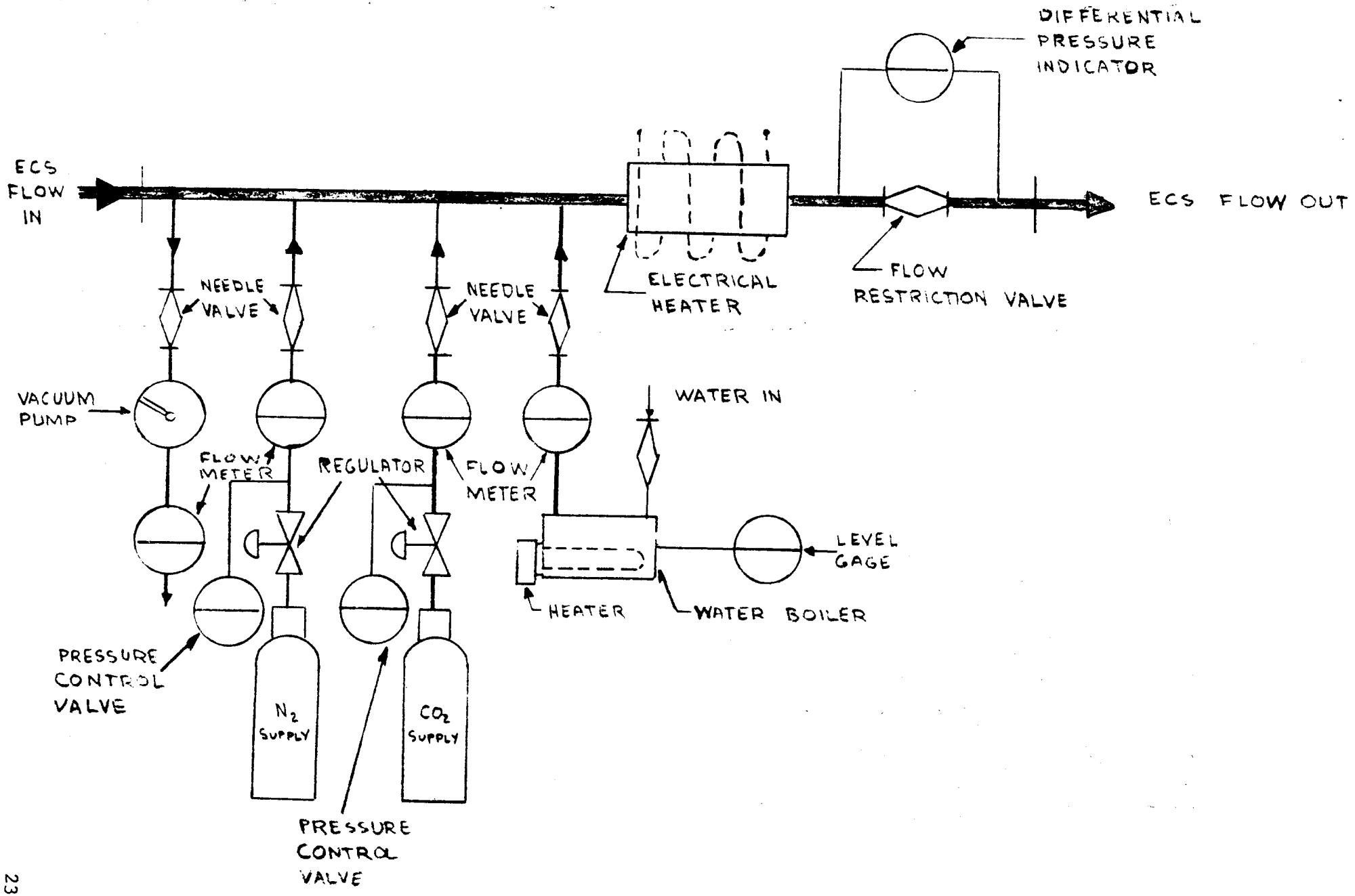


FIGURE 1 SCHEMATIC DIAGRAM, MAN SIMULATOR

5.5.4.3.1 Metabolic oxygen consumption will be simulated by a metered flow from the system to a vacuum pump and vented to the atmosphere. The pump will also remove water vapor and carbon dioxide from the system, but since these are only trace constituents, they may be neglected or correction factors may used in calculations. A metered flow from a regulated nitrogen will make up the difference in nitrogen removed from the ECS flow by the vacuum pump.

5.5.4.3.2 Metabolic carbon dioxide production will be simulated by a metered flow from a regulated carbon dioxide source.

5.5.4.3.3 Metabolic water vapor production will be simulated by a metered flow from a water boiler.

5.5.4.3.4 Sensible heat input will be produced from an electrical coil heater in the flow path.

5.5.4.3.5 Flow restriction will be accomplished in the man simulator by manually altering the open flow area of a butterfly type valve in the flow path.

5.5.4.4 Functional Test Preparation

5.5.4.4.1 Couple the man simulator to the ECS module to be tested.

5.5.4.4.2 Install differential pressure gage across ECS blower inlet and outlet.

5.5.4.4.3 Install exterior line temperature sensor on:

5.5.4.4.3.1 Coolant inlet line to heat exchanger.

5.5.4.4.3.2 Coolant outlet line to heat exchanger.

5.5.4.4.4 Install interior flow temperature sensor probes in:

5.5.4.4.4.1 Flow into heat exchanger.

5.5.4.4.4.2 Flow from heat exchanger.

5.5.4.4.5 Reference differential ECS-to-chamber pressure switch to high vacuum source (1 mm Hg abs or less) to simulate chamber pressure. There is no differential ECS-to-chamber switch in the case of the RECS.

5.5.4.4.6 Attach water vapor and CO analyzers to sampling port located after heat exchanger.

5.5.4.5 Pre-Test Activity

5.5.4.5.1 Prior to activation of the ECS for evaluation, valves, switches, controls, etc., should be set as indicated in the ECS operating procedure (to be prepared by the vendor).

5.5.4.5.2 The flow restriction in the simulator should be full open prior to starting the ECS blower.

5.5.4.6 ECS Adjustments, Operational Checks, and Maintenance - CO_2 canister recharging, draining of condensate, air flow adjustment, and other normal system maintenance operations are described in the ECS operating procedure.

5.5.4.7 ECS Test Sequence

Prior to taking any data the system should be operating at a "steady state" condition at the desired test parameters. All normal operating tests may be conducted at once or on an individual basis as desired.

5.5.4.7.1 Blower

The flow restriction in the man simulator is to be set at the maximum anticipated suit-umbilical (or manlock-line), in the case of the RECS) pressure drop level as set forth in the specification. This is accomplished by manually adjusting the flow restriction valve and reading the pressure drop across the restriction. The flowmeter in the ECS system will then indicate the maximum anticipated flow for the worst pressure drop condition. The differential pressure gage across the blower will indicate the pressure rise in the blower which when reduced by the pressure drop across

the man simulator will indicate the pressure drop in the remainder of the system.

5.5.4.7.2 Heat Exchanger, Evaporator, Condensing Unit Coolant Pump, and Condensate Collector

Maintain system at maximum flow condition as described in section 3.4 of the ECS specification. Adjust the man simulator to generate the maximum anticipated sensible heat and water vapor input condition as described in section 3.4 of the ECS specification. Continuously record the temperature of coolant in and out of heat exchanger. Also record the water vapor content of the conditioned oxygen flow by means of the sensor located at the heat exchanger exit. Alternate humidity readings shall be taken after the CO_2 absorbers. The above recorded values should not exceed the design limitations. The water in the condensate collector shall be measured and compared to the input quantity.

5.5.4.7.3 CO_2 Absorber

Maintain system at maximum flow condition as described in section 3.4 of the specification. Adjust the carbon dioxide input flow to the maximum anticipated condition as described in specification. Record the resulting history of CO_2 partial pressure in the oxygen flow by means of the ECS CO_2 analyzer. The CO_2 absorber should maintain the CO_2 partial pressure below the critical level for a period of time as set forth in the specification.

5.5.4.7.4 Oxygen Make-Up

Adjust the oxygen removal flow to the maximum anticipated condition as described in the specification. Record the make-up flow and compare to the removal flow.

5.5.4.7.5 System Pressure and Oxygen Partial Pressure

The system absolute pressure should compare with the sum of the oxygen partial pressure, the carbon dioxide partial pressure, the nitrogen partial pressure and the water vapor partial pressure.

5.5.4.7.6 CO Presence

The CO analyzer will determine the degree to which the toxic gas, carbon monoxide, is present in the system. Any level above 50 ppm or any rising trand in CO level should be investigated. Also gas samples will be taken to be analyzed by mass spectrograph to determine the presence of other toxic materials.

5.5.4.7.7 Emergency Oxygen Make-Up - (Does not apply to the RECS)

Disconnect normal oxygen make-up subsystem and evaluate the results of a simulated ruptured umbilical by evacuating the space simulator chamber. When the system pressure reaches 2.0 PSIA at the blower inlet, the emergency make-up oxygen flow should be automatically activated and should operate till the pressure at the blower inlet reaches 2.5 PSIA This cycle should be completed several times.

5.5.4.7.8 Reheater

Adjust the man simulator to simulate one man in the ECS and two men in the case of the RECS with the ventilating circuit of the ECS maintaining the ventilating flow rate as described in the specification and the test procedure (to be generated by the vendor). Adjust the coolant flow to the heat exchanger to maintain the minimum specified temperature. Record the heat exchanger coolant in and out temperatures and the ventilating flow temperatures in and out of the heat exchanger and reheater. The resulting

flow temperatures after the reheater should compare with those specified. This cycle should be completed several times to assure that the heat exchanger and reheater can maintain the specified ventilating flow temperatures.

APPENDIX B

RESCUE ENVIRONMENTAL CONTROL SYSTEM DESIGN CONSIDERATIONS

INTRODUCTION

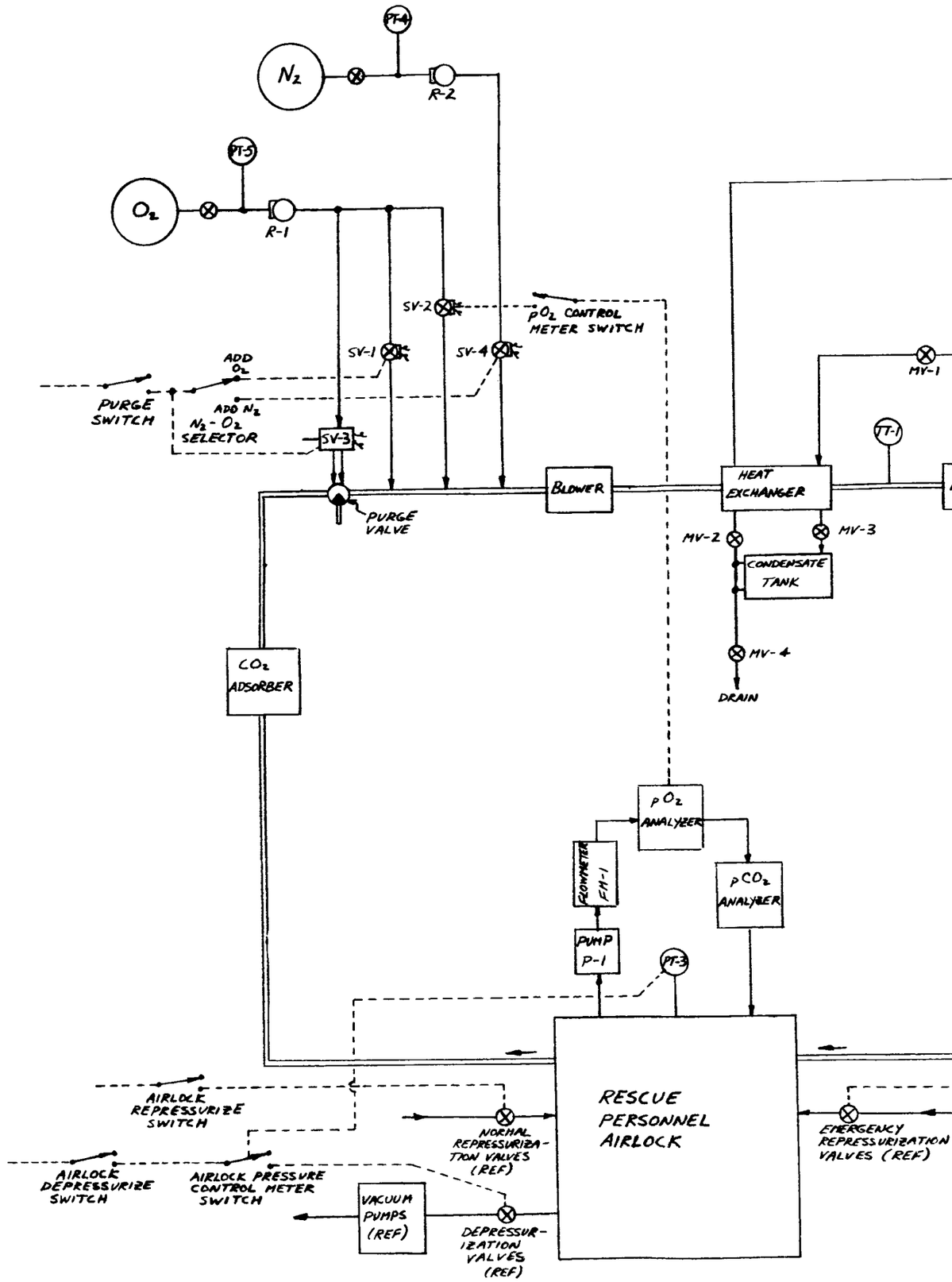
The schematic of the Rescue Personnel Environmental Control System (RECS) is shown in Figure 1-B. While a detailed layout of the RECS has not been prepared, the general arrangement of the components would be similar to the Test Personnel ECS (see drawing 201R803).

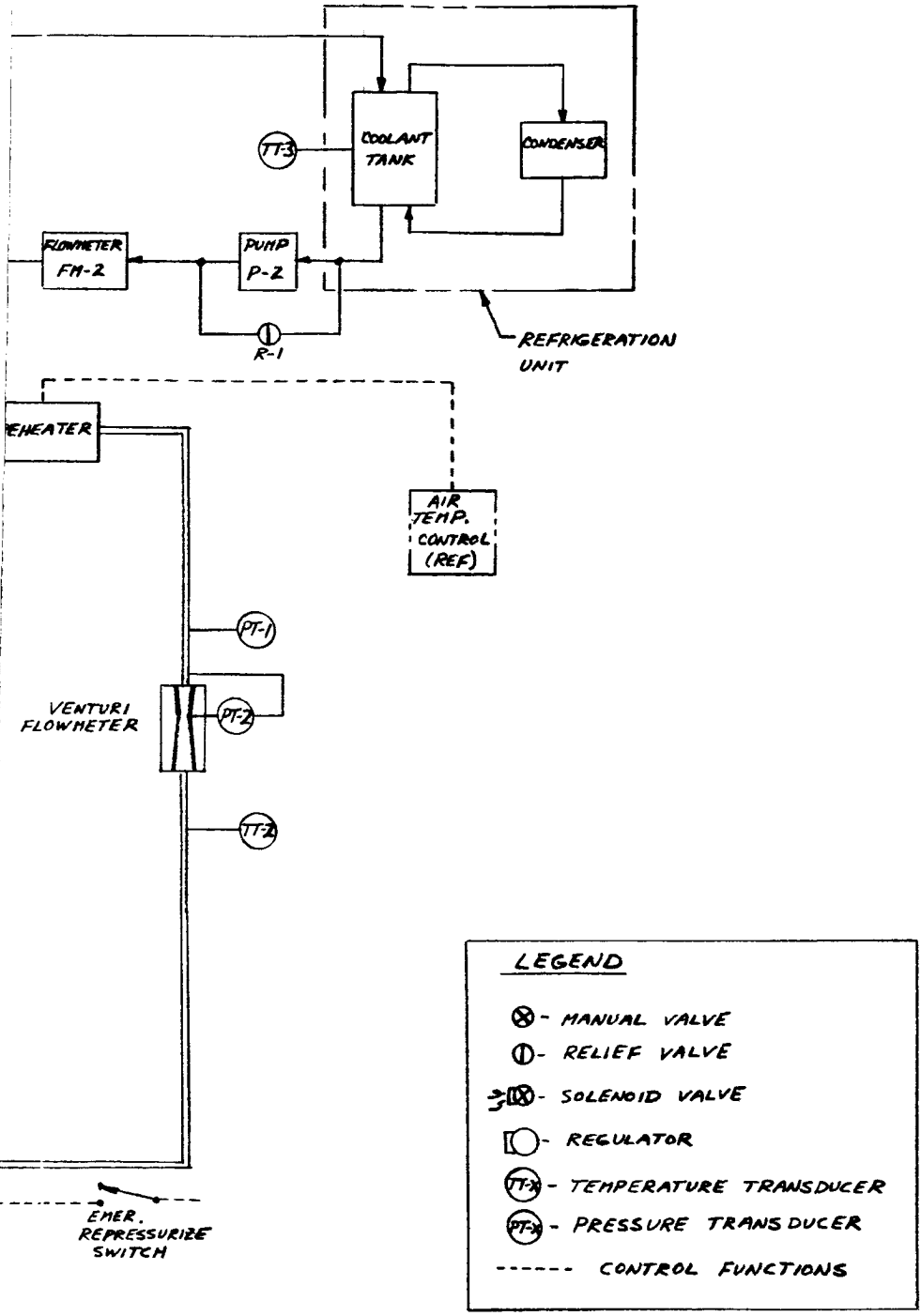
The function of the RECS is to provide a viable environment within the rescue personnel manlock for the unsuited rescue personnel. This is accomplished by controlling the atmosphere composition, pressure and temperature within the specified limits. The RECS functions as a closed loop system, receiving "stale" air from the manlock, processing this air, and delivering the conditioned air back to the manlock. In discussing the design of the RECS, it is simplest to separate the RECS into its three main functional subsystems: the air circulation loop; the coolant loop; and the pressurization control subsystem.

SYSTEM DESIGN

Air Circulation Loop

The function of the air circulation loop is to circulate and condition the air within the manlock. With the help of the schematic (Figure 1-B), the air flow can be traced through this closed loop system.


PT-4
N_2
R-2
PT-5
O_2
R-1
SV-2
pO_2 CONTROL METER SWITCH
SV-1
SV-4
ADD O_2
PURGE SWITCH
ADD N_2
N_2 - O_2 SELECTOR
SV-3
MV-1
TT-1
BLOWER
HEAT EXCHANGER
PURGE VALVE
MV-2
MV-3
CONDENSATE TANK
MV-4
DRAIN
CO_2 ADSORBER
pO_2 ANALYZER
FLOWMETER FM-1
pCO_2 ANALYZER
PUMP P-1
PT-3
AIRLOCK REPRESSURIZE SWITCH
NORMAL REPRESSURIZATION VALVES (REF)
RESCUE PERSONNEL AIRLOCK
EMERGENCY REPRESSURIZATION VALVES (REF)
AIRLOCK DEPRESSURIZE SWITCH
AIRLOCK PRESSURE CONTROL METER SWITCH
VACUUM PUMPS (REF)
DEPRESSURIZATION VALVES (REF)



MECHANICAL SCHEMATIC - RECS

FIG. 1-B

DJW - 11/19/65

Air, from the manlock, enters the RECS and is directed to the CO_2 absorber canister. The air from the manlock has picked up moisture (latent heat), sensible heat, CO_2, and trace contaminants from the metabolic processes of the men. Additional sensible heat has been added to the air from airlock equipment, such as lights. The air is also slightly deficient in oxygen due to metabolic consumption. In the CO_2 absorber canister, CO_2 is removed from the air by passing the air through baralyme. The baralyme chemically combines with the CO_2 forming carbonates and releasing water. A small charge of activated charcoal is also used in the CO_2 absorber canister to remove trace gas impurities and odors from the air.

From the CO_2 canister, the air passes through the blower. The blower imparts sufficient energy to the air to circulate it through the RECS and manlock at the required flow rate. Next the air flows through the heat exchanger. The sensible and latent heat picked up by the air from metabolic and equipment heat loads are rejected to the coolant loop in the heat exchanger. The air leaving the heat exchanger is thus both cooled and dehumidified. Water, condensed out of the air, flows to, and is stored in the condensate tank.

The cool, dry air then enters the reheater, where its temperature is raised by contact with a finned electrical heater. By varying the power input to the heater, the air temperature to the manlock can be controlled. The conditioned air is then delivered through the venturi flow meter to the manlock.

There is one additional component in the air circulation loop, namely, the purge valve. This is a three way flapper or ball valve having one inlet port and two outlet ports, and is located between the CO_2 absorber canister and the blower. Normally, the outlet port to the blower is open, and the outlet port to ambient is closed, and the air circulates through the RECS as described above. During purge operation, however, the outlet port to the blower is closed and the port to ambient is open. In this case, oxygen, entering the loop between the valve and the blower, flows through the RECS and airlock and exits to ambient through the purge valve, thus purging the system.

Coolant Loop

The function of the coolant loop is to provide a heat sink for the air flow through the heat exchanger. To provide this function, a refrigeration unit is utilized to maintain a reservoir of coolant (40% ethylene glycol - 60% water) at $34^{\circ}F$. This coolant is then pumped through the heat exchanger, where it picks up the heat rejected by the air. A flow meter and manual throttling valve are provided to adjust the coolant flow rate. A by-pass relief valve is also installed to protect the pump, should the coolant lines become plugged for any reason.

Pressurization Control Subsystem

The pressurization control subsystem maintains the selected atmosphere total pressure and oxygen partial pressure within the manlock. It also provides for purging the RECS and manlock prior to airlock decompression. The design of the pressurization control system

can best be explained by describing the sequence of events that occur in the operation of the system.

Prior to the test, manlock operating total pressure as well as the manlock operating oxygen partial pressure (pO_2) is selected. The limit switch contacts on the pO_2 control meter are adjusted to open at the desired pO_2 control level. The limit switch contacts on the manlock total pressure control meter are set to open at the desired total pressure control level.

The RECS is now turned on. This starts the blower, coolant pump, and condenser unit, and applies power to the controls. At this point, the blower will be circulating the ambient air in the manlock through the system. The two rescue personnel enter the manlock and close the door. The atmosphere within the manlock and RECS now has to be adjusted so that, after the manlock is pumped down to its operating pressure, the proper atmosphere composition will result. This adjustment takes place by purging the RECS and manlock with oxygen. The purge switch is flipped to "on" position, which actuates the purge valve and opens solenoid valve SV-1. Oxygen then flows completely through the system and the manlock and exits to ambient through the purge valve, flushing nitrogen out of the system. The length of the purge is governed by the atmosphere composition desired. For example, if a 50/50 O_2/N_2 atmosphere is required, the oxygen purge would continue until the manlock atmosphere was 50% O_2, 50% N_2. If a single gas atmosphere is required, the oxygen purge would continue until essentially all the nitrogen is flushed from the manlock, and the atmosphere is 100% O_2.

In practice, it is expected that this purging of the manlock and RECS will be accomplished manually, by the operator at the control console. That is, he would leave the purge switch on for the approximate length of time required to provide the proper O_2 concentration. He would then turn the switch off and read the pO_2 and total pressure gauges to determine the exact O_2 percentage. If more O_2 were required, the purge would continue. If less O_2 is required, N_2 can be added to the system by actuating the N_2 add switch which opens valve SV-4. In this manner, small adjustments are made until the atmosphere composition corresponds to the desired value.

The manlock is now ready for depressurization. This is accomplished by actuating the manlock depressurize switch. This opens the valves from the manlock to appropriate chamber vacuum pump (or pumps) and removes atmosphere from the manlock. The RECS, of course, since it is connected to the manlock, is depressurized at the same time. When the manlock pressure has dropped to the desired operating pressure, the switch contacts of the manlock total pressure control meter open, and the valves to the vacuum pump close, preventing further evacuation of the manlock.

System total pressure is then maintained by the pressure control meter switch working in conjunction with the valves to the vacuum pump. As the manlock pressure rises, due to leakage, the switch closes, the valves open and the manlock pressure is lowered. When the pressure reaches the lower set point, the switch opens and the valves close. The system oxygen partial pressure is maintained independently of the system total pressure. As the pO_2 falls, due to metabolic consumption,

the pO_2 control meter switch closes. This opens solenoid valve SV-2, adding oxygen to the system. When the pO_2 rises to the upper control limit, the switch opens and SV-2 closes.

When it is desired to repressurize the manlock to ambient, the manlock depressurize switch is turned off and the manlock repressurize switch is turned on. This opens the inbleed valves and the manlock and RECS are brought up to ambient pressure.

COMPONENT DESIGN AND ANALYSIS

Blower

The blower must provide a flow of 100 CFM through the system in order to remove metabolic and equipment heat while maintaining manlock temperature within the specified limits. The pressure drop through the system, at this flow rate and standard conditions, is calculated to be 12 in. H_2O. This is assuming that the RECS is placed close to the manlock, thus minimizing line losses. The blower selected is a Joy Manufacturing Co. axivane fan, model No. AVF-35-27D1320, part no. X702-248. This blower will provide a flow of 100 CFM against a back pressure of 15.4 in H_2O. Thus, assuming the system characteristics given above (100 CFM at 12 in. H_2O), this blower would produce a flow of 110 CFM through the system (110 CFM at 14.5 in H_2O).

The blower operates on 200 V, 400 cycle AC, 3 phase power. The input horsepower at the above design conditions is 0.68, or 510 watts. When operating at lower pressures, the blower is unloaded, and the power input is lower. At 3.5 psia, the power input would be approximately

$\frac{(3.5)\ (510)}{(14.7)}$ = 120 watts. The CFM at these lower pressures would remain essentially constant, since the system pressure drop would vary in the same proportion as the blower delivery static pressure and blower speed remains essentially constant.

CO_2 Absorber Canister

The CO_2 absorber canister utilizes baralume to absorb the CO_2 produced by the crew. The amount of baralyme required is:

Maximum duration = 12 hours

Average metabolic rate = 450 BTU/HR/man (very light activity, sitting)

O_2 consumption (assuming 1 liter of O_2 consumed will produce 4.83 Kcal of metabolic heat)

$$= 450 \frac{\text{BTU}}{\text{HR.}} \times 0.252 \frac{\text{Kcal-hr.}}{\text{BTU}} \times \frac{1}{4.83} \frac{\text{liter}}{\text{Kcal}}$$

= 23.5 liters/hr/man

Assuming an R.Q. of 0.82

CO_2 produced = (0.82) (23.5) = 19.3 liters/hr/man

= 16.4 ft^3 for 12 hours for 2 men (total)

Since CO_2 @ STP = 0.1225 lbs/ft^3

wt. CO_2 produced = (0.1225) (16.4) = 2.01 lbs. $\approx$ 2.0 lbs.

Therefore the baralyme must absorb 2.0 lbs. of CO_2. The theoretical capacity of baralyme for CO_2 is 0.435 lb. CO_2/lb. baralyme. Assuming an absorption efficiency of 75% (based upon previous evaluation tests with an identical canister configuration) and using a factor of safety of 25%, the amount of baralyme required is:

$$\text{wt. baralyme} = \frac{(2.0)\ (1.25)}{(0.435)\ (0.75)} = 7.67 \text{ lbs.}$$

The density of the loaded baralyme pellets is 0.0314 lbs/in^3 therefore:

$$\text{Vol. of baralyme req'd.} = \frac{7.67}{0.0314} = 244 \text{ in}^3$$

The CO_2 canister must be sized to accomodate 260 in^3 of chemicals, 244 in^3 of baralyme, and 16 in^3 of charcoal. When charging the canister, the charcoal, used to adsorb odors, should be dispersed throughout the baralyme.

The design of the CO_2 canister should be similar to that designed for the test personnel ECS (reference drawing 101D1340). The canister for the RECS must be larger than that for the ECS in order to accomodate the increased amount of chemicals.

Heat Exchanger

The heat exchanger provides cooling and dehumidification of the ventilating air flow. The calculations for sizing the heat exchanger are as follows:

Heat Load

The maximum heat load on the heat exchanger occurs when the manlock and system pressure is 14.7 psia (maximum pressure) and the maximum reheater power is utilized.

Metabolic Heat Load

Assume 450 BTU/HR. as the average metabolic heat production per man. The division of sensible and latent heat production depends on the manlock dry bulb temperature. Since, with maximum reheater power, the air temperature inlet to the manlock is 80°F, the manlock air temperature is (assuming adiabatic walls):

$$T_a - T_{in} = \frac{Q_{as}}{\dot{\omega}\, C_p}$$

where T_a = manlock temp., °F

T_{in} = air inlet temp., °F

Q_{as} = sensible heat production in manlock, BTU/HR.

$\dot{\omega}$ = air flow rate, lb_m/hr.

C_p = air specific heat, $\frac{BTU}{lb_m\text{-}^oF}$

now Q_{as} = sensible heat production by man, Q_{ms}, plus sensible heat production by equipment, Q_{es}

Assume, Q_{ms} = 150 BTU/hr/man

Q_{as} = 100 watts = 342 BTU/HR.

then Q_{as} = (150) (2) + 342 = 642 BTU/HR.

now $\dot{\omega}$ = (ρ) (CFM) (60)

where ρ = air density, lb_m/ft^3 = 0.075

CFM = air flow, ft^3/min. = 110

$\dot{\omega}$ = (0.075) (110) (60) = 495 lb_m/hr.

Thus T_a - 80 = $\frac{642}{(495)\ (.024)}$

T_a = 85.4°F $\approx$ 85°F

Now, for a total metabolic heat production of 450 BTU/hr/man, the latent heat output:

Q_{ml} = 290 BTU/hr/man (11) = 580 BTU/hr total, and the sensible heat output:

Q_{ms} = 160 BTU/hr/man (11) = 320 BTU/hr. total

Baralyme Sensible Heat Load

Baralyme releases 330 BTU/hr. for every lb. of CO_2 absorbed.

$\therefore$ Q_{bs} = (330) (CO_2) BTU/hr.

where CO_2 = CO_2 production rate, = 0.167 lb_m/hr.

Q_{bs} = 55 BTU/hr.

Baralyme Latent Heat Load

Baralyme releases 0.75 lb. H_2O for every lb. of CO_2 absorbed.

$$Q_{bl} = (0.75)\ (L)\ (CO_2)$$

where L = latent heat of vaporization = 1050 BTU/lb_m

$$Q_{bl} = 131 \text{ BTU/hr.}$$

Blower Heat Load

Since the blower is mounted in line, and the motor is cooled by the ventilating air stream, assume all blower power is dissapated in the air stream.

Thus Q_{fs} = 510 watts = 1740 BTU/hr.

Reheater Heat Load

Assume $T_{air\ out}$ of heat exchanger = 45°F.

Then,

$$Q_{rs} = \dot{m} C_p\ (T_{air\ out} - T_{air\ in})$$

$$= (495)\ (0.24)\ (80 - 45)$$

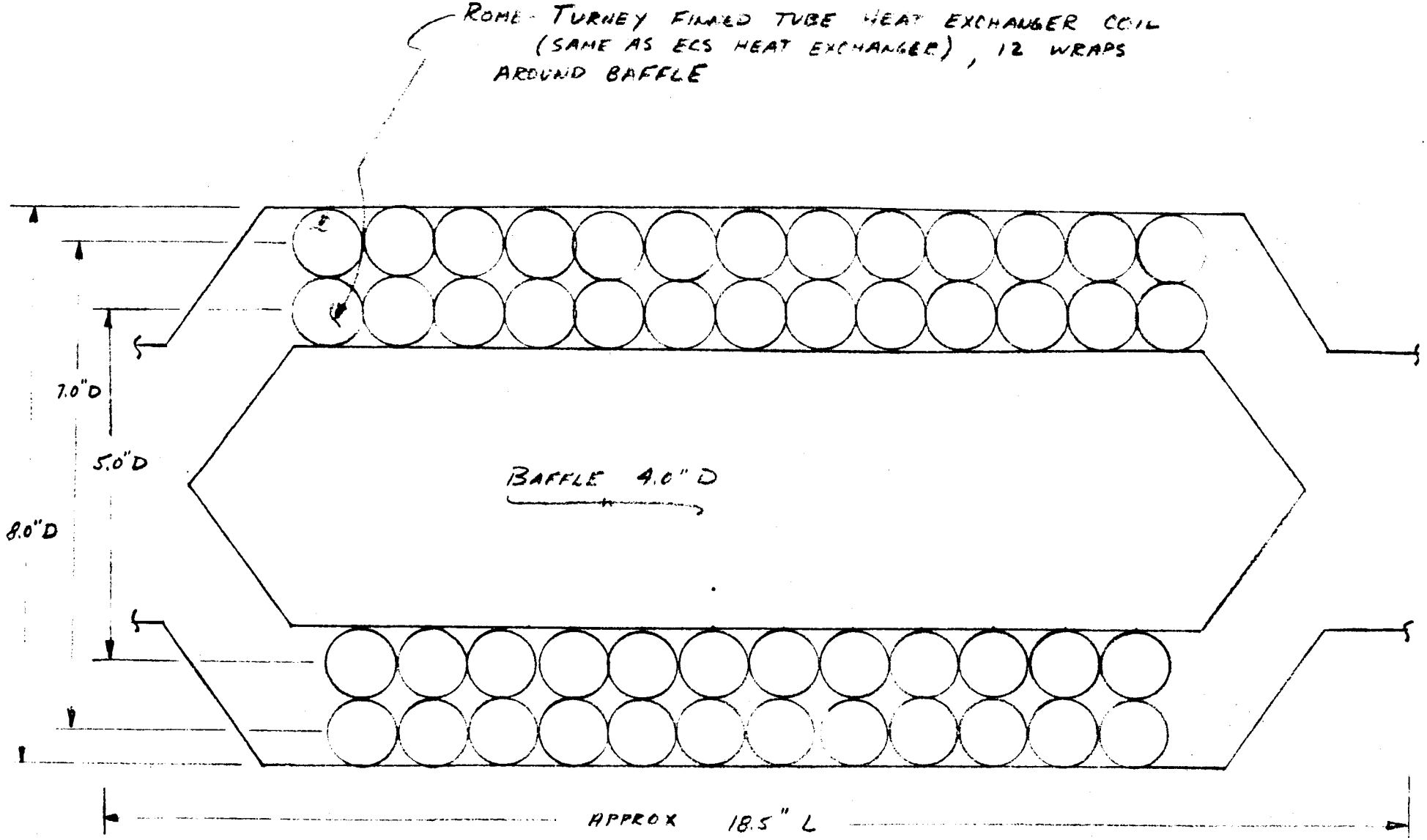
$$= 4160 \text{ BTU/hr.}$$

Heat Load Summary

BTU/HR.

	Sensible	Latent	Combined Load
1. Metabolic	320	580	900
2. Airlock Equip.	342	-	342
3. Baralyme	55	131	186
4. Blower	1740	-	1740
5. Reheater	4160	-	4160
TOTALS	6617	711	7328

The heat transfer coefficients for the air and liquid sides of the heat exchanger can now be estimated. The Heat Exchanger Configuration is as shown in Figure 2-B. This configuration is similar to the ECS heat exchanger design except that a double row of Rome-Turney heat exchanger coil is utilized. This provides the extra heat exchange surface to handle the higher heat loads of the RECS, and minimizes pressure drop due to the larger flow area.



RECS HEAT EXCHANGER CONFIGURATION

FIG. 3

Air Side

Reynolds number, Rey = $\frac{\rho V 4 r_h}{\mu}$

where ρ = air density = 0.075 lb_m/ft^3

V = air velocity, ft/sec

r_h = hydraulic radius, ft.

μ = air viscosity = 120 x 10^{-7} lb_m/sec-ft.

Now, $V = \frac{CFM}{(60)\ (A)}$ where A = free flow area, ft^2

also $\sigma^{(10)}$ = $\frac{\text{free flow area}}{\text{frontal area}}$ = 0.538

and frontal area = $\frac{\frac{\pi}{4}(8)^2 - \frac{\pi}{4}(4)^2}{144}$ = 0.261 ft^2

$\therefore$ A = (0.538) (0.261) = 0.14 ft^2

and V = $\frac{110}{(60)\ (0.14)}$ = 13.1 ft/sec.

$4\ r_h^{(10)}$ = 0.0154

and Rey = $\frac{(0.075)\ (13.1)\ (0.0154)}{120\ x\ 10^{-7}}$ = 1260

now from (10) $\left(\frac{h}{G c_1}\right) P_r^{2/3}$ = 0.011

where h = heat transfer coefficient, BTU/hr-ft^2-^{o}F

$$G = \rho V \ (3600) \ lb_m/hr\text{-}ft^2$$

$$P_r = \frac{c_p \mu}{K} \ (3600) = 0.71$$

$$\text{thus} \quad h = \frac{(0.011)\ (0.24)\ (0.075)\ (13.1)\ (3600)}{(0.71)^{2/3}}$$

$$h = 11.7 \ BTU/hr\text{-}ft^2\text{-}^oF$$

This heat transfer coefficient is based on only sensible cooling of the air. Since there is also a latent heat load, and condensing occurs in the heat exchanger, this coefficient will be higher. However, since the latent heat load is a small percentage (about 10%) of the total load, the heat transfer coefficient will be used as derived above. This will provide a safety factor in the design of the heat exchanger.

Coolant Side

Assume a coolant flow rate of 3 gal/min. and an inlet temperature of 34^{o}F. The temperature rise of the coolant through the heat exchanger is:

$$T = \frac{Q}{\dot{\omega} \ c_p}$$

where Q = heat load = 7328 BTU/hr.

$\dot{\omega}$ = coolant flow rate, $lb_m/hr.$

C_p = coolant specific heat, $BTU/lb_m\text{-}^oF$

now $$\dot{\omega} = 3 \frac{gal}{min.} \times 60 \frac{min.}{hr.} \times 0.134 \frac{ft^3}{gal.} \times \rho$$

where ρ = coolant density = $66.1\ lb_m/ft^3$

$\therefore \dot{\omega} = 1590\ lb_m/hr.$

also $C_p = 0.81\ BTU/lb_m\text{-}^oF$

thus $$T = \frac{7328}{(1590)\ (0.81)} = 5.7^oF$$

Other coolant properties (based on a mean temperature of 37^oF) are:

Coolant - 40% ethylene glycol - 60% water

$K = 0.252\ BTU/hr\text{-}ft^2\text{-}^oF/ft$

$\mu = 1.15 \times 10^{-4}\ lb_f\text{-}sec/ft^2$

$P_r = 42.8$

now $Re_y = \frac{\rho VD}{\mu}$ where D = tube inside dia., ft.

$$V = \frac{\dot{\omega}}{(3600)\ \rho\ A}$$ where A is tube flow area = $0.001112\ ft^2$

$$V = \frac{(1590)}{(3600)\ (66.1)\ (0.001112)} = 6 \text{ ft/sec.}$$

$$\text{and Rey} = \frac{(66.1)\ (6)\ (0.0266)}{(1.15 \times 10^{-4})\ (32.3)} = 2850$$

now, from (5)

$$\left(\frac{h}{G c_p}\right) P_r^{2/3} = 0.0023$$

$$\text{and } h = \frac{(0.0023)\ (0.81)\ (66.1)\ (6)\ (3600)}{(42.8)^{2/3}}$$

$$h = 218 \text{ BTU/hr-ft}^2\text{-}^\circ\text{F}$$

The amount of heat exchanger tubing required can now be calculated

$$Q = UA\ (LMTD)$$

$$\text{where LMTD} = \frac{(T_{\text{air in}} - T_{\text{coolant out}}) - (T_{\text{air out}} - T_{\text{coolant in}})}{\ln \dfrac{(T_{\text{air in}} - T_{\text{coolant out}})}{(T_{\text{air out}} - T_{\text{coolant in}})}}$$

now $T_{\text{air in}} = T_{\text{air out}}$ of airlock + Δ T gained across baralyme and blower

now $T_{air\ out}$ of airlock = $85.4^{o}F$

and $$\Delta T = \frac{Q_{bs} + Q_{fs}}{\dot{\omega} \quad C_p}$$

$$\Delta T = \frac{55 + 1740}{(495)\ (0.24)} = 15.1^{o}F$$

thus $T_{air\ in} = 85.4 + 15.1 = 100.5^{o}F$

Also, let $T_{air\ out} = 45^{o}F$, under these max. load conditions

Thus $$LMTD = \frac{(100.5 - 39.7) - (45 - 34)}{ln \frac{(100.5 - 39.7)}{(45 - 34)}}$$

$$LMTD = 29.1^{o}F$$

and $$UA = \frac{Q}{LMTD} = \frac{7328}{29.1} = 252\ BTU/hr\text{-}^{o}F$$

now $$\frac{1}{UA} = \frac{1}{h_{air}\ A_{air}} + \frac{1}{h_{coolant}\ A_{coolant}}$$

(neglecting conduction through the tube, and using a fin effectiveness of 1. From data on the heat exchanger tubing;

$A_{air} = 0.89\ L\ ft^2$ where L is the length of tubing.

$A_{coolant} = 0.0835\ L\ ft^2$

$$\text{Thus } \frac{1}{252} = \frac{1}{(11.7)\ (0.89)\ L} + \frac{1}{(218)\ (0.0835)\ L}$$

and $L = 38$ ft.

for this heat exchanger configuration, each wrap of the double coil about the 4" dia. baffle, requires a tubing length of:

$$L = \frac{\pi(5) + \pi(7)}{12} = 3.14 \text{ ft.}$$

$$\text{Thus, no. of wraps of coil} = \frac{38}{3.14} \approx 12$$

Therefore, the heat exchanger design, as shown in Figure 2-B, with twelve wraps of the double coil around a 4" dia., baffle will contain 38 ft of heat exchanger coil, and is sufficient to reject the maximum heat load of the system.

Condensate Tank

The condensate tank must store all the water condensed in the heat exchanger over the twelve hour mission. The maximum amount of condensate that will be produced is:

Metabolic Water Production

The maximum metabolic latent heat load will occur at the highest airlock atmosphere temperature.

Thus Q_{ml} = 580 BTU/hr total

and H_2O produced $= \frac{580}{L} = \frac{580}{1050} = 0.55$ lb/hr

Baralyme Water Production

H_2O produced = (0.75) (0.617) = 0.125 lb/hr

Therefore, the maximum amount of water condensed in the heat exchanger is

H_2O = (0.55 + 0.125) (12) = 8.1 lbs.

The volume required to store this water is 225 in^2. Thus, the condensate tank should be designed to store 250 in^3 of water, allowing for a safety margin. The design should be similar to the condensate tank of the ECS, (reference Drawing 113C8795) except for increasing the diameter and/or length slightly to provide additional storage volume.

Reheater

The function of the reheater is to control the temperature of the air inlet to the manlock. This is accomplished by supplying heat energy, in controlled amounts, to the cool air leaving the heat exchanger. The construction of the RECS reheater should be similar to the ECS reheater, except that a different finned tubular electrical heater is employed, and this is

wound around a 5" diameter baffle. By varying the current through the electrical heater, the heat input and thus the air outlet temperature, can be accurately controlled.

The maximum reheat energy required is 4160 BTU/hr. = 1220 watts. The heating element selected is "Chromalox" (mfg. by Edwin L. Wiegand Co.) type FTS-54412. This finned tubular heater has a surface area of about 66 in^2. Thus the watt density is:

$$\frac{1200}{66} = 18.5 \text{ watts/in}^2 \text{ max.}$$

This heater, when wound around a 5" diameter baffle, will have a free flow area of about 12.8 in^2.

The velocity over the heater is then

$$V = \frac{CFM\ (144)}{(60)\ A} = \frac{(110)\ (144)}{(60)\ (12.8)} = 20.6 \text{ ft/sec}$$

From vendor data, for a watt density of 18.5 watts/in^2, and an air velocity of 20.6 ft/sec., the sheath temperature of the heater will be 650°F, with an air temperature of 80°F. This is below the maximum allowable sheath temperature limit of 750°F, and thus is adequate for the RECS reheater requirements.

Refrigeration Unit

The refrigeration unit maintains the coolant reservoir at 33 $\pm$1.5°F. The unit is of conventional design, with the evaporator coils located within the coolant tank, and the condenser rejecting the heat to the ambient air.

The maximum heat load on the refrigeration unit is:

RECS Heat Load = 7328 BTU/hr.

Pump Heat Load

Assume all pumping power is dissipated as heat into the coolant flow.

$$\text{Pumping power} = \frac{(\dot{\omega})\,(H)}{33{,}000} \quad \text{horsepower}$$

$\dot{\omega}$ = coolant flow rate, lb_m/min

H = head, ft.

The pump (Eastern Industries, Model 2F-34) is rated at 3 gal/min. at 25 psi head.

$$\text{now } \dot{\omega} = 3\ \frac{gal}{min} \times 0.138\ \frac{ft^3}{gal} \times 66.1\ \frac{lb_m}{ft^3} = 27.4\ lb_m/min$$

$$\text{and } H = \frac{(25)\ (144)}{(66.1)} = 54.5\ ft.$$

$$\text{thus Power} = \frac{(27.4)\ (54.5)}{33{,}000} = .045\ HP = 115\ BTU/hr.$$

Coolant Tank Jacket Losses

Assuming the jacket losses will be about the same as for the ECS coolant tank,

Q = 182 BTU/hr.

Total Heat Load

RECS	7328	BTU/hr.
Pump	115	
Jacket Losses	182	
TOTAL	7625	BTU/hr.

The Filtrine Manufacturing Co., Cooler Model PC-100-AL would be adequate to meet the RECS requirements. This cooler includes the coolant reservoir and the refrigeration unit, with the appropriate controls to maintain a coolant outlet temperature of 33 $\pm$1.5°F. The condenser is rated at 8500 BTU/hr. at an ambient of 90°F, and a evaporating temperature of 25°F. The coolant storage capacity of 8 gallons is the same as the ECS unit.

Oxygen and Nitrogen Requirements

The RECS requires oxygen as make-up for metabolic consumption. Oxygen and nitrogen are also required to purge the rescue personnel manlock. The amounts of oxygen and nitrogen required, and the flow rates required, are given below.

Oxygen Make-Up

When the RECS is operating normally, the crew will consume oxygen from the manlock atmosphere. As the pO_2 falls, the low limit switch on the pO_2 control meter (which is driven by the O_2 analyzer) closes and solenoid valve SV-2 opens. Oxygen from the supply cylinder is then free to flow into the RECS. As the pO_2 rises, the high limit switch on the pO_2 control meter closes, which closes SV-2, shutting off the oxygen flow. The requirements for valve SV-2 are as follows:

O_2 consumption, for two men at a metabolic rate of 450 BTU/hr/man = 1.66 ft^3/hr.

Now assume manlock + RECS volume = 370 ft^3

Thus, pO_2 will fall at the rate of $\frac{1.66}{370} \times 760 = 3.4$ mm Hg/hr.

Thus, if the high and low set points for pO_2 were 10 mm Hg. apart, i.e., pO_2 would be held at a set value $\pm$ 5 mm Hg., the valve would open once every $\frac{10}{3.4} \approx 3$ hours.

At each valve opening, 1.66 x 3 = 4.98 $\approx$ 5 ft^3 of oxygen must be added. A reasonable length of time over which this oxygen addition would occur is about 1 minute. Thus the valve should supply an O_2 flow of about 5CFM.

The inlet pressure to the valve is governed by the setting of the cylinder regulator R-1. This component is a pressure reducing and regulating valve that reduces the O_2 cylinder pressure to a steady output pressure. A reasonable outlet pressure is 100 psi. Thus, valve SV-2 must supply a flow of 5 CFM of oxygen, when the inlet pressure is 100 psi, and the outlet pressure is 3.5 to 14.7 psia.

Oxygen Purge

An oxygen purge is required to initially adjust the atmosphere within the manlock and RECS to provide the proper oxygen concentration. When the purge switch on the console is switched on, the purge valve actuates and solenoid valve SV-1 opens. The purge valve then blocks off the normal airflow route through the ECS, and allows the O_2, flowing through SV-1 to purge through to RECS, the manlock and exit to ambient.

The detail design of the purge valve has not been accomplished; however, in concept, the valve should be a three way flapper or ball valve, with one common inlet port, and two outlet ports. The valve should be actuated by a pneumatic cylinder, such that in one position, the outlet port to the blower is open, and the outlet port to ambient is closed, and in the other position, the open and closed outlet ports are reversed. A four way pilot solenoid valve, SV-3, is used to direct gas to either side of the piston of the pneumatic cylinder. In this manner, depending on the position of valve SV-3, the cylinder rod will extend to contract, moving the valve flapper or ball. O_2 is used to power the pneumatic cylinder, and this is taken downstream of regulator R-1.

The amount of oxygen required in the purge is calculated as follows:

Assume complete mixing of the purge oxygen with the manlock atmosphere, such that 100% O_2 is delivered to the manlock, and a mixture of N_2 and O_2 vents to ambient.

Then $Q = \rho V \left(1 - e^{-\frac{C_o + C}{V}}\right)$

where Q = amount of oxygen in manlock, lbs.

V = manlock volume, ft^3

ρ = density of O_2, lb_m/ft^3

C_o = volume of oxygen (STP) in manlock initially, ft^3

C = volume of oxygen (STP) added during purge, ft^3

The maximum amount of oxygen required occurs when a 100% O_2 manlock atmosphere is required. For practical purposes, the above equation can be used to calculate this amount of oxygen, based on an oxygen concentration of 95%. (It can be seen that, using this equation, obtaining a 100% O_2 atmosphere would require an infinite amount of purge oxygen. This results from the assumption of complete mixing of the entering O_2 with the manlock atmosphere, used to derive the equation. In fact, there will be some oxygen concentration gradient, from the inlet port to the outlet port of the manlock).

Thus Q, at 95% concentration $= \rho V \times 0.95$, where V is assumed $= 370\ ft^3$, and

ρ (STP) $= 0.089\ lb_m/ft^3$

$Q = (0.089)\ (370)\ (.95) = 31.3$ lbs.

Thus $31.3 = (0.089)\ (370)\ \left(1 - e^{-\frac{C_o + C}{370}}\right)$

and $1 - e^{-\frac{C_o + C}{370}} = 0.95$

$e^{-\frac{C_o + C}{370}} = 0.05$

and $\frac{C_o + C}{C_o} = 3$; $C_o + C = 1110\ ft^3$

now $C_o = (\rho\ O_2)(V)$ where $\rho\ O_2$ = density of O_2 in air, lb_m/ft^3

$= 0.0187\ lb_m/ft^3$

$C_0 = 70\ ft^3$

Thus C = $1040\ ft^3$ = the maximum amount of O_2 required to purge the manlock.

The flow rate of O_2 through the solenoid valve SV-1 must be sufficent to accomplish this purge in a reasonable time, say 10 minutes. The flow rate should then be about 100 CFM, when the inlet pressure is 100 psi, and the outlet pressure is 14.7 psi.

A standard 1800 psi oxygen cylinder contains 305 ft^3 of oxygen when full. Thus, at least four O_2 cylinders are required to insure an adequate oxygen supply. The cylinders would be manifolded together, and connected to a common regulator.

Nitrogen Requirements

The manlock and RECS will operate, normally, at lower than ambient pressures. Thus, there will be inleakage from ambient to the RECS and manlock. There also will be leakage from the manlock, through the chamber door, to the chamber. If however, we assume that leakage occurs primarily around seal areas, the amount and length of seals exposed to the ambient/manlock Δ P is greater than that exposed to the chamber/manlock Δ P. Thus the net effect of the leakage should be that of a leak into the system.

Thus the manlock and RECS pressure should slowly rise during operation. Total pressure is maintained by the setting of manlock pressure control meter switch. As the pressure rises, the switch closes, opening the valves to the vacuum pump, bringing the pressure down to the set point. Under these conditions, no nitrogen addition to the system is required, since pO_2 is maintained independently of the system total pressure, and pN_2 will simply be the difference between pO_2 and total pressure.

Suppose now, that, for some reason, the net leakage is out from the system, causing manlock pressure to slowly decay. If a 100% oxygen atmosphere is used, this causes no problem, since the effect will be that of slightly higher O_2 consumption. The pO_2 control meter will maintain total pressure by controling valve SV-2. If a two gas atmosphere is utilized, the pO_2 meter control will maintain a set pO_2, but total pressure may decline. It is anticipated that, under these conditions, the console operator could manually control the total pressure by opening the manlock inbleed valves for a short duration. This would allow ambient air to flow into the airlock and raise the total pressure to the desired value. Again, this operation requires no separate N2 control or supply, other than ambient air.

Nitrogen addition may be required to adjust the manlock atmosphere, prior to decompression, and a N_2 supply system is shown on the schematic for this purpose. It would be used if, during purge, too much oxygen is added, and the O_2 percentage "overshoots" and is too high. Nitrogen is then added to reduce the pO_2 to the desired level. One cylinder of nitrogen should be more than sufficient to meet this demand. Again, a pressure regulator, R-2, is used to reduce bottle pressure to 100 psi, and a solenoid valve, SV-4, used to control the N_2 flow. Flow rate of the solenoid valve should be on the order of 15 to 20 CFM to provide a fine "trim" effect on the atmosphere composition.

RESCUE ENVIRONMENTAL CONTROL SYSTEM DESIGN SPECIFICATION

1. SCOPE

This specification establishes the design requirements for a Rescue Environmental Control System (RECS) to be used in conjunction with the NASA-Langley Research Center (LRC) space environment simulation chamber airlock. The following requirements are established to define a system which accomplishes all the life support functions necessary to maintain two men within the chamber airlocks under all modes of airlock operation.

2. APPLICABLE DOCUMENTS

2.1 Government and Military Documents

The following documents in effect on the date of issuance of this specification form a part of this specification to the extent described herein.

Specifications

MIL-Q-5923	Quality Control Requirements, General
MIL-W-8160 D	Wiring, Guided Missile, Installation of

Standards

MIL-STD-130 B	Identification & Marking of Equipment
MS-33586	Metals, Definition of Dissimilar

2.2 Other Publications

The following documents, in effect on the date of issuance of this specification form a part of this specification to the extent defined herein.

Drawings

Later	Mechanical Schematic, RECS
Later	Assembly, RECS
Later	Electrical Schematic, RECS

3. REQUIREMENTS

3.1 Description of the RECS

The rescue environmental control system will be capable in normal operation of sustaining up to two unsuited subjects within one of the two space environmental simulation chamber airlocks. The rescue environmental control system, (RECS) is defined as that equipment external to the airlock necessary to sustain the viability of two subjects in the airlock in a "shirtsleeve" environment. Included in this definition are all allied external interconnnecting lines, penetration fittings or blanks, cabling, system instrumentation, control devices and consoles. All umbilicals, fittings, manifolds, cabling and instrumentation that are inside the airlock are not considered a part of the RECS.

Except for the above mentioned cabling, interconnenting lines, etc., the RECS shall be designed as a self-contained module and shall be located external to the space invironmental simulation chamber airlock with external distribution piping which connects airlock penetrations to the RECS module. The RECS will operate as a closed loop system in which gases are recirculated between the man and the RECS package in order to permit accurate control of environmental parameters and to provide the capability for obtaining viability test data.

The RECS shall perform the following basic life support functions:

a. Ventilating/Breathing Oxygen Circulation

b. Sensible/Latent Heat (Moisture) removal

c. CO_2 Removal

d. Total Pressure Regulation

e. Monitoring/Control Instrumentation

Drawing (later) "Mechanical Schematic, RECS", illustrates the sequence these functions shall follow along the main ventilating flow path.

3.2 General Requirements

(Same as paragraph 3.2 of Chamber ECS Design Specification SVS 7431)

3.3 Design and Construction

3.3.1 Structural Configuration

The design configuration of the environmental control system shall be in conformance with drawing (later), "Rescue Environmental Control System Assembly."

3.3.2 Electrical Configuration shall conform to the requirements of Drawing (later), Electrical Schematic RECS.

3.3.3 Structural Integrity

All RECS atmosphere ventilating circuitry, accessories, piping, etc., shall be structurally designed to withstand a 15 PSI external-to-internal pressure differnetial with the lower pressure on the internal side. The system shall be capable of withstanding a 5 PSI differential in the opposite direction as well (i.e., 20 PSIA internal pressure and 15 PSIA external ambient pressure).

3.3.4 Leak Tightness

The entire RECS installation shall be leak tight to the extent that inward leakage of air shall not increase the RECS internal total pressure by more than 2 mm Hg per 24 hrs. when the RECS internal pressure is 3.5 psia and the ambient pressure is 14.7 psia.

3.3.5 Design Life

The ECS equipment shall be designed to have an operating life of twenty years. Only normal maintenance and minor parts

replacement (e.g. pumps, blowers etc.) should be required during this period.

3.4 Performance

3.4.1 External Environments

(Same as paragraph 3.4.1 of Chamber ECS Design Spec SVS 7431)

3.4.2 Internal Airlock Environmental Control Functions

The RECS shall perform the following environmental control (life support) functions.

3.4.2.1 Ventilating Oxygen Circulation

The ECS module shall deliver a constant 100 CFM at a temperature of 50°F which is independent of the airlock pressure.

3.4.2.2 Pressure Regulation

Pressure regulation equipment for operation during both normal and emergency conditions (emergency chamber repressurization) shall be provided as described below. The capability for purging the system of undesired gases prior to operation shall be provided. Provisions shall also be made for pressure regulation during airlock pump down and normal repressurization procedures.

3.4.2.2.1 Pressure Regulation During Normal Operation

During normal operation, the pressure regulation apparatus shall give the capability for controlling the system total pressure to any given setting between 3.5 and 19.7 psia with a $\pm$ 0.2 psi tolerance. An oxygen partial pressure regulator shall be used. Make-up oxygen shall be supplied from a high pressure (2000 PSIA) oxygen cylinder and shall be 100% aviator's breathing oxygen or equivalent.

This pressure regulation subsystem shall be capable of supplying oxygen to the system at flow rates up to 5 CFM as make-up for metabolic consumption and leakage.

3.4.2.2.2 Pressure Regulation Emergency Atmosphere Make-Up

The RECS shall be provided with an emergency atmosphere make-up circuit which is capable of providing make-up atmosphere at a rate sufficient to maintain two personnel in the airlock at ambient during the occurance of a gross leak to the evacuated chamber. The emergency make-up circuit must be capable of performing the former task under the extreme flow condition which would result from the occurence of a gross break or malfunction in the airlock to chamber seals. The emergency make-up circuit shall prevent the pressure in the airlock from dropping below 3.5 PSIA, when subjected to a maximum leak rate of 3.3 #/min.

The emergency make-up circuit shall be provided with a manual override such that the entire RECS may be pressurized to 5 PSI higher than the ambient laboratory pressure in order to facilitate the locating of leak sources during pretest check outs.

3.4.2.2.3 Purging of RECS

The RECS shall have the capability for purging the airlock prior to its operation. Purging will be accomplished by flushing the entire system internal volume with 100% oxygen. Oxygen then flows completely thru the system and the airlock, and exits to ambinet thru the purge valve, flushing nitrogen out of the system. The length of purge is governed by the atmosphere composition desired.

3.4.2.3 Temperature Control

The system temperature control apparatus shall maintain the ventilating oxygen from any of the RECS outlets at various temperatures between $50^{o}F$ and $80^{o}F$ within a tolerance of $\pm 2^{o}F$ for any given setting. The RECS shall be capable of supplying up to 100 CFM to the airlock at the above conditions.

3.4.2.4 Humidity Control

The humidity control apparatus to be indicated within the RECS module shall maintain the specific humidity of the oxygen atmosphere between 4 and 8 mm Hg measured at the RECS penetration outlet to the airlock. Water removal capability shall equal or exceed the net rate of 1.0 lb. per hour (generated by two men at a rate of 450 BTU/HR Man). Provisions shall be made for the periodic removal of accumulated excess moisture from the system without having to interfere with the operation of the RECS. (The RECS shall have the capability for continuous operation for periods up to twelve hours).

3.4.2.5 CO_2 Removal

The CO_2 removal apparatus shall be capable of maintaining the CO_2 partial pressure in the airlock below 8 mm Hg for normal operation with up to two men.

3.4.2.6 Odor Removal

A means shall be provided to remove noxious odors from the system. The odor removal absorbent/adsorbent shall be mixed with the CO_2 absorbent in suitable proportions.

3.4.3 Monitoring and Control Instrumentation

The majority of system parameters shall be monitored and displayed remotely, and as a consequence these read-out specifications are to be found in a separate document.(SVS-7435). However, a number of monitoring instruments shall be located on the RECS.

3.4.3.1 Coolant Pump Flow Rate

The total flow rate from the coolant circuit to the heat exchanger shall be measured at the RECS. The design flow rate is 3 GPM at 30 PSI. The flowmeter readout shall have a 0 to 4 GPM range with an overall accuracy of $\pm$ 2% of maximum flow from 10 to 100% of full flow.

3.4.3.2 Analyzer Pump Flow Rate

The total flow rate thru the analyzer circuit shall be measured. The design flow is 2 to 3 CFH. The flowmeter readout shall have a 0 to 5 CFH range with an overall accuracy of ± 2% of maximum flow from 10 to 100% of full flow.

3.4.3.3 Oxygen Partial Pressure

The oxygen partial pressure in the airlock shall be measured and displayed at the RECS. An output signal suitable for a recorder input shall also be provided. Read out full scale range shall be 0-1200 mm Hg. A suppressed scale range of 0-300 mm Hg shall also be provided. Overall accuracy is ± 2%.

3.4.3.4 CO_2 Partial Pressure

The airlock CO_2 partial pressure shall be measured and displayed on the RECS. An output signal suitable for a recorder input shall also be provided. Full scale range of readout shall be 0-20 mm Hg. with an overall accuracy of ± 2%.

4.1 GENERAL

The components for the RECS shall meet the environmental requirements of this specification.

4.2 Acceptance Testing

The entire RECS installation shall be tested in accordance with the procedures specified in the ECS Acceptance Procedure Plan to be found in Spec SVS 7431.

APPENDIX C

UMBILICAL DESIGN CONSIDERATIONS

DESIGN ANALYSIS

The design analysis for the umbilical subsystem is based on supporting two full pressure suited subjects in the NASA LANGLEY 55' chamber in conjunction with remote, permanent ECS installations.

The umbilicals are capable of supplying ventilating gas, metabolic oxygen, coolant for temperature control, hard wire biomedical signals, and hard wire communications. The umbilical shall be designed to be as flexible as possible consistent with adequate strength and leak integrity.

Development testing on representative sections of umbilical will have to be performed in order to formulate meaningful bending stiffness relations for assessing minimum bend radii. The overall weight of the umbilical subsystem is minimized to reduce the loads imposed on the suited subjects. The heat loss or gain from coolant or ventilating lines is minimized to reduce the overall load on the ECS temperature control system.

Oxygen Line Design Calculations

A study of suit pressure drops and ventilating requirements were made on existing full pressure suits. Mercury, Gemini, and Apollo suits were included in this study which is summarized below:

SPACE SUIT DESIGN CRITERIA

APPLICATION	OXYGEN FLOW	OXYGEN PRESS DROP	SUIT LEAK RATE	MAX PRESS	H_2O FLOW RATE	H_2O PRESS DROP
Mercury	10 CFM	2" H_2O at rated flow & 3.7PSIA	200 cc/ min	5 PSID	—	—
Gemini	11.5 CFM	5" H_2O at rated flow & 3.7 PSIA	200 cc/ min	5.5 PSID	—	—
Apollo	6 CFM	4" H 0 at rated flow & 3.7 PSIA	—	5.0 PSID	4#/min	4 PSI

For sizing the oxygen lines the Gemini oxygen flow rate was chosen; that is, 11.5 CFM.

Calculating a Reynolds number for this flow: (Reference 5)

$R_D = \frac{\rho VD}{\mu}$

(Assume .875" dia. hose)

ρ = weight density, #/ft.^{3}

V = velocity, ft./sec.

D = diameter, feet

μ = viscosity, #/sec. ft.

$$\text{Area} = \frac{(.875)^2 \pi}{4} = .603 \text{ in.}^2$$

$$\text{Velocity} = \frac{Q}{A} = \frac{11.5 \text{ ft}^3/\text{min.} \times 144 \text{ in}^2/\text{ft.}^2}{.603 \text{ in}^2 \times 60 \text{ sec/min}} = 45.9 \text{ ft./sec.}$$

Viscosity O_2 = 202 micropoise (Reference 6, p. 2221)

Single, 202 micropoises = .0202 centipoise

And .000672 $\frac{\text{centipoise}}{\#/\text{sec. ft.}}$ (Reference 12, page 244)

Therefore, Viscosity oxygen at 70°F = 13.56×10^{-6} lb/sec. ft.

$$R_D = \frac{.083 \#/\text{ft.}^3 \times 45.9 \text{ ft/sec.} \times .875 \text{ in} \times 10^6}{13.56 \text{ lbs./sec. ft.} \times 12 \text{ in./ft.}}$$

$$R_D = 20{,}500$$

Types of Flow	Reynolds No.
Laminar	Up to 1500
Transition	1500 to 2300
Turbulent	over 2300

The oxygen hose pressure drop can be computed using the following basic equation. However, the friction factor depends on Reynolds number, hose roughness, and material.

$$\Delta P = 4 f \frac{L}{D} \frac{\rho V^2}{2g}$$ (Reference 5, section G-402.1)

ΔP = pressure drop, lb/ft^2
L = length of pipe, ft.
g = acceleration of gravity, 32.2 $ft^2/sec.$
D = pipe equivalent dia., ft.
ρ = fluid weight density, $lb./ft^3$
V = average velocity of flow, ft/sec.
f = friction factor, dimensionless

$$\Delta P = 4\ (.01^*)\ \frac{110}{.875} \times 12 \times \frac{.083\ \ (45.9)^2}{2\ (32.2)}$$

* Based on smooth tube (Reference 5, section G-402.3)

$$\Delta P = \frac{164\ lbs/ft^2}{144\ in^2/ft^2} = 1.14\ PSI = 31.5\ in.\ H_2O\ @\ 14.7\ PSIA$$

The above pressure drop accounts for the 7/8" I.D. hose. The suit and quick disconnect pressure drops are added to arrive at the overall system oxygen pressure drop @ 14.7 PSIA.

Umbilical	31.5 inches of water
Quick Disconnect	4.0 inches of water
Suit (Gemini)	19.9 inches of water @ design flow (11.5 CFM)
	51.4 inches of water total P

Since the ECS is capable of providing a pressure head of 55.3 inches of water, the 7/8" I.D. tubing was selected for the oxygen line in the umbilical subsystem.

Vendor empirical data indicates that a pressure drop of 30.3 inches of water will exist with an oxygen flow of 11.5 CFM, 7/8"I.D. straight hose, and 19.7 PSIA pressure. Test data indicates that the pressure drop will increase very little with a 180^o bend because of the generous radius involved.

Actual maximum expected pressure drop @ 14.7 PSIA is therefore:

Umbilical	22.8 inches of water
Quick Disconnect	4.0 inches of water
Suit (Gemini)	19.9 inches of water
	42.7 inches of water

As an example of typical suit circuit pressure characteristics @ various

operating pressures, Figure I-C, shows a plot of pressure drop vs flow, this curve includes pressure drop through umbilical quick disconnects and suit pressure drop.

Coolant Line Design Calculations

The coolant lines are designed around the Apollo suit application since this suit is the only one presently utilizing a liquid cooling system. The Apollo suit utilizes a 4 #/min flow rate or 0.45 gallons/minute with the 40% glycol 60% water, by weight, solution to be utilized as a coolant. To be consistent with the Apollo suit a 3/8 inch I.D. line was considered for initial pressure drop calculations.

Viscosity for 40% glycol - 60% water, be weight, is 3.75 centipoises (Reference 6, page 2025).

$$3.75 \text{ centipoise} \times .000672 \frac{\text{centipoise}}{\#/\text{sec. ft.}} * = 2.52 \times 10^{-3} \#/\text{sec. ft.}$$

* (Reference 12, page 244)

Calculating volume flow:

$$\frac{4.0 \#/\text{min} \times 60 \text{ min/hr}}{66.1 \#/\text{ft}^3 *} = 3.63 \text{ ft}^3/\text{hr.}$$

* (Reference 7, section 2, page C-27)

$$\text{Velocity} = \frac{3.63 \text{ ft}^3/\text{hr.} \times 144 \text{ in}^2/\text{ft}^2}{.111 \text{ in}^2 \times 3600 \text{ sec./hr.}} = 1.31 \text{ ft/sec.}$$

The Reynolds number for the above flow is:

$$R_D = \frac{\rho VD}{\mu}$$

$$R_D = \frac{66.1 \text{ lbs/ft}^3 \times 1.31 \text{ ft/sec.} \times .375 \text{ in.}}{2.52 \times 10\text{-}3 \text{ lbs/sec. ft.} \times 12 \text{ in./ft.}} = 1077$$

The above Reynolds number clearly shows the flow to be in the laminar flow region.

The pressure drop through 110' of 3/8 inch I.D. nylon tubing will be:

$$\Delta P = 4 f \times \frac{L}{D} \times \frac{V^2}{2} \quad \text{(Reference 5, section G 402.1)}$$

$$\Delta P = 4\ (.009) \times \frac{110}{.375} \times \frac{66.1\ (1.31)^2}{2\ (32.2)} = 1.762 \text{ PSI}$$

The overall coolant loop pressure drop will be:

Umbilical (110 ft)	1.76 PSI
Quick Disconnects	0.20 PSI
Suit (Apollo)	4.00 PSI
	5.96 PSI TOTAL

Discussion

Assembly

The umbilical design shown on drawing 113C8797 presents a universal, approach to making the umbilical compatible with all full pressure suits presently utilized. The oxygen lines have been sized for 11.5 CFM, the Gemini oxygen flow rate. This flow rate is the highest of the three suits considered. The coolant lines are included in the design and sized for 4 lbs/min, the Apollo coolant flow. The Apollo oxygen requirements are only 5 CFM when coolant is utilized for absorbing the metabolic heat load. Thus the umbilical could be optimized for any given suit making it lighter, more flexible and less bulky. For example, if a Gemini suit is to be used, the coolant lines can be eliminated, greatly reducing the umbilical cross section. If an Apollo suit is to be tested, the oxygen lines can be reduced to approximately one half inch I. D. to accommodate the 6 CFM oxygen flow. Three umbilical assemblies are specified on drawing 113C8797. These assemblies differ only in length, G1 being 55 foot long for use in the chamber, G2 being 15 foot long for use in the airlock, and G3 being 10 foot long for use in the denitrogenation facility.

The R. E. Darling Company has expressed an interest in fabricating the umbilical assembly. This company did the fabrication of the Gemini Four 25 foot tether. A proposed price for the umbilical assembly is included in the cost estimate attached to this report.

Oxygen Line

The material utilized in the oxygen line must be compatible with the oxygen-rich atmosphere it will be exposed to, and must not out gas noxious or toxic contaminants. Flexibility, leak tightness, low pressure drop and reliability are other considerations in selecting the material for the oxygen hose. For these reasons silicone rubber, wire reinforced, fabric covered, smooth bore hose was selected. This hose is produced by the R. E. Darling Company and is currently used almost exclusively on all flight oxygen systems.

Coolant Line

Nylon tubing was selected for the coolant lines because of its high strength and dimensional stability.

Wiring

The thirty-two, number 21, shielded and stranded leads are divided into four bundles of eight wires for increased flexibility. All shielding is tied into a common "ground" pin at the connector. A breakdown of the wire requirements are as follows:

Function	Number of Wires
Voice	2
ECG	2
Respiration	2
Inlet Temperature	2
Outlet Temperature	2
Deep Body Temperature	2

The R. E. Darling Company has expressed an interest in fabricating the umbilical assembly. This company did the fabrication of the Gemini Four 25 foot tether. A proposed price for the umbilical assembly is included in the cost estimate attached to this report.

Oxygen Line

The material utilized in the oxygen line must be compatible with the oxygen-rich atmosphere it will be exposed to, and must not out gas noxious or toxic contaminants. Flexibility, leak tightness, low pressure drop and reliability are other considerations in selecting the material for the oxygen hose. For these reasons silicone rubber, wire reinforced, fabric covered, smooth bore hose was selected. This hose is produced by the R. E. Darling Company and is currently used almost exclusively on all flight oxygen systems.

Coolant Line

Nylon tubing was selected for the coolant lines because of its high strength and dimensional stability.

Wiring

The thirty-two, number 21, shielded and stranded leads are divided into four bundles of eight wires for increased flexibility. All shielding is tied into a common "ground" pin at the connector. A breakdown of the wire requirements are as follows:

Function	Number of Wires
Voice	2
ECG	2
Respiration	2
Inlet Temperature	2
Outlet Temperature	2
Deep Body Temperature	2

Skin body Temperature		2	
Suit Pressure		2	
Amplifier		3	± 12V & GRD
Shielding Ground		1	
Pressure Control Interlock Circuit		3	
	Sub-total	23	
	Spares	9	
	TOTAL	32	Wires

Insulation

The wiring and tubing described above is potted in place using an open cell, flexible urethane foam. The potting serves to position the wiring and hose and also serves as an effective insulation. Since solar simulation or cryogenic panels are not incorporated in the 55 foot chamber, this insulation is adequate.

Umbilical Covering

A continuous nylon braided sleeve is utilized for an outer covering. This covering is designed to withstand the abrasion and wear expected of the umbilical in service.

Umbilical Test Fixture

A separate test fixture, drawing 101D1344, has been provided for check-out of the umbilical pneumatic lines, hydraulic lines, and electrical continuity. This fitting can be mounted at a convenient location on the chamber of airlock wall permitting the suit end of the umbilical to be retained when not in use. Both the ECS system and the umbilical assembly can be checked out prior to connecting a suited individual to the system. Coolant lines, oxygen lines, and hard wire are short circuited permitting flow and continuity checkout, as well as leak testing.

Umbilical Harness & Biomedical Sensor Locations

The umbilical harness, shown on drawing 201R806, is provided to position and support the umbilical coupler. The harness is designed to fit over a full pressure suit and support a portion of the umbilical weight. This harness may also be used to support the oxygen supply tank when traversing between the denitrogenation facility and the airlock.

Umbilical Cover & Restraint

A protection and retention bracket for the umbilical-chamber connection is provided as shown on drawing 253E551. This bracket is designed to eliminate excessive stress on the individual oxygen, coolant, or electrical connections; as the umbilical is moved about the chamber. The connections at this end of the umbilical are semi-permanent and would remain connected after a chamber mission. Cover plates on the top and front will protect these vulnerable connections from inadvertant damage.

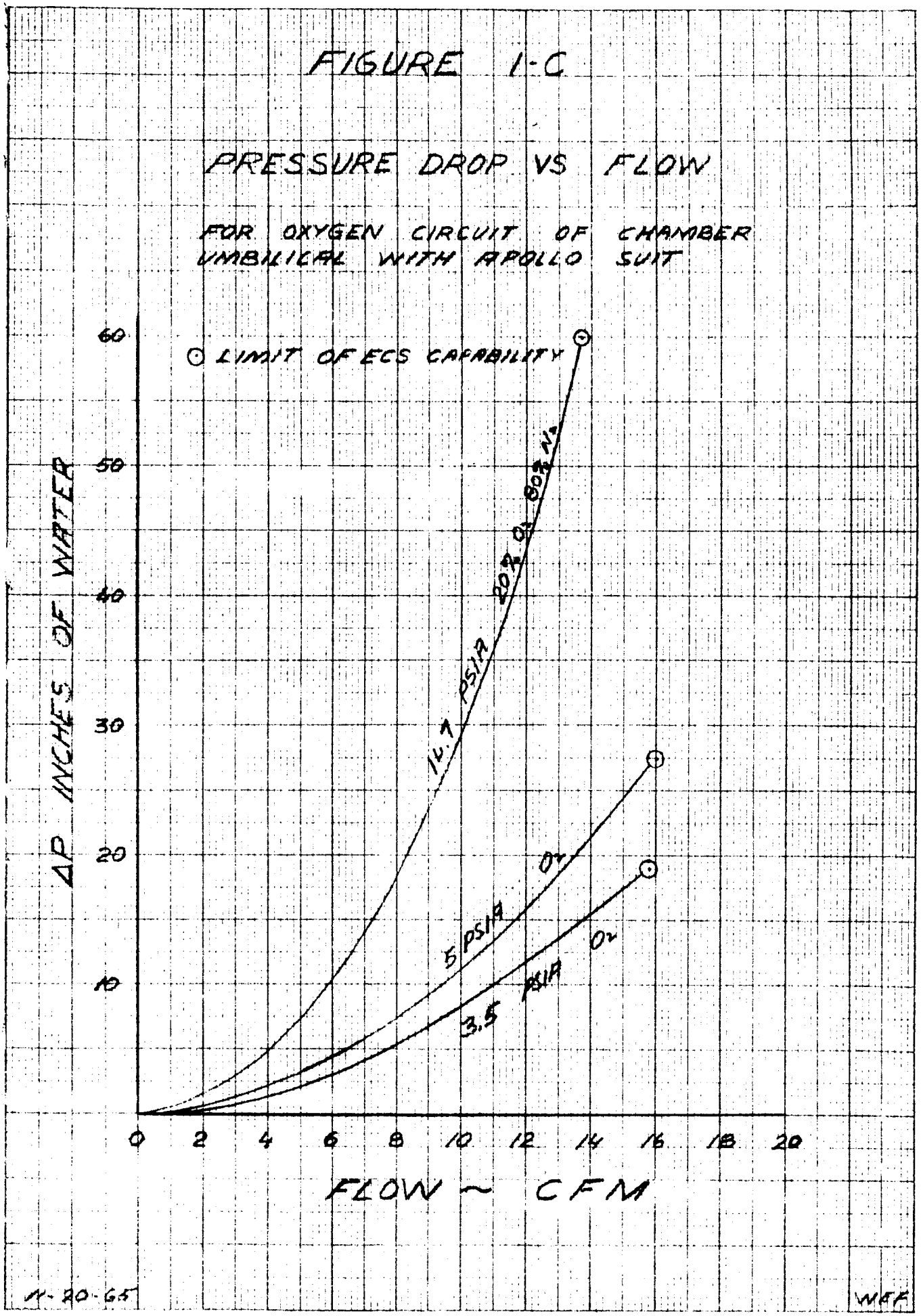
Umbilical Coupler Assembly

The coupler assembly was provided to permit all the required umbilical interface connections (electrical & pneumatic) to be severed or joined by activation of a single common device. The coupling was designed to be operated by a full pressure suited subject applying a force of 45 pounds. The suit half of the coupling contains a redundant coupling which permits a subject to connect to the main umbilical before he disconnects from the airlock umbilical. Both halves of the quick disconnect fittings utilized contain check valves which will prevent loss of suit, or ECS pressure, when disconnected. The check valve is opened mechanically as the two portions of the quick disconnect are coupled.

FIGURE 1-C

PRESSURE DROP VS FLOW

FOR OXYGEN CIRCUIT OF CHAMBER UMBILICAL WITH APOLLO SUIT



4-20-65

WAF

SVS 7433

SPECIFICATION FOR

UMBILICAL SUBSYSTEM

1.0 SCOPE

1.1 Description

This specification establishes the minimum performance and physical requirements for the design, manufacture, and testing of an umbilical subsystem. This umbilical portion of the subsystem shall consist of two 7/8 I.D. oxygen lines (inlet and outlet), two 3/8 I.D. coolant lines (inlet and outlet), and a communications/bioinstrumentation harness. The aforementioned lines shall be integrated into a common, single, umbilical assembly. These lines shall terminate at one and in a quick disconnect coupling that has self-sealing capabilities and is separable by means of a single actuation device. Three different umbilical assemblies are specified on the umbilical assembly drawing 11368797. These assemblies differ only in length; one being 55 foot long for use in the chamber, one is 15 feet long for use in negotiating between the manlock and the chamber, and the third is 10 feet long for use in the denitrogenation facility.

The subsystem shall also include an umbilical checkout fixture to check out each umbilical before use with test subjects.

1.2 Purpose

The umbilical subsystem shall be utilized to convey ventilating oxygen, liquid coolant (if required), communications wire, and bio-instrumentation from the vacuum chamber interface to a full pressure suited

individual located inside the Langley 55' Vacuum Cylinder.

2.0 APPLICABLE DOCUMENTS

2.1 Responsibility of Manufacturer

The manufacturer shall comply with the following specifications and other publications to the extent applicable and shall establish any new requirements which may become necessary to provide materials which will operate satisfactorily under the conditions required of this specification. The need for absolute reliability throughout the assembly is essential since breakdown of a component may very quickly result in the death or serious injury of the subject.

2.2 Applicable Publications

The following government documents of the issue listed form a part of this specification to the extent specified herein.

Federal Specifications

MSFC Spec. 164 July 27, 1964	Cleanliness of Components for use in oxygen, fuel and pneumatic systems.
O-T-634	Trichlorocthylene, Technical
QCS-100-0	Quality Control Systems

Military Specifications

MIL-E-8160D 24 Dec. 1963	Wiring, Guided Missile, Installation of
MIL-W-16878 5 July 1961	Wire, Electrical
MIL-D-70327 27 March 1962	Drawings, Engineering and Associated Lists
MIL-P-116D 4 Dec. 1962	Preservation, Methods Of

MIL-STD-130B 24 April 1962	Identification and Marking of U.S. Military Property
MS-33586 16 Dec. 1958	Metals, Definition of Dissimilar
MIL-S-7742A 3 Dec. 1959	Screw Threads, Standard, Aeronautical
MIL-F-7179	Finishes and Coatings
MIL-Q-9858 9 April 1959	Quality Control System Requirements
MIL-H-22489 24 Aug. 1962	Hose Assemblies, Low Pressure, Breathing Oxygen and Air

Drawings

Umbilical Test Fixture	101D1344
Umbilical Coupler Ass'y.	201R801
Umbilical Ass'y.	133C8797
Umbilical Cover & Restraint	253E551
Umbilical Harness and Biomedical Sensor Locations	201R806

3.0 GENERAL REQUIREMENTS

3.1 Identification

Marking shall be in accordance with MIL-STD-130 and the applicable drawings listed in Paragraph 2.2.

3.2 Shelf Life and Service

The umbilical assembly shall be capable of operation within the requirements of this specification after storage periods of up to two years. The assembly shall be capable of operating for extended periods of time.

3.3 Design and Construction

3.3.1 Umbilical Assembly

The umbilical assembly shall be constructed to the configuration, dimensions and details shown in drawing 113C8797. The umbilical is designed for maximum flexibility consistent with adequate strength and leak integrity. The umbilical assembly must be capable of withstanding a pressure differential of 15 PSI on the oxygen line and 21 PSIA on the coolant line; in addition, pressure differentials of 15 PSI in a reverse direction shall not cause collapse or buckling of the oxygen lines. The materials utilized in the construction of this assembly must be compatible with oxygen, water/glycol, and a vacuum environment. The detail design under this specification shall strive for minimize size and weight and maximum flexibility consistent with practical consideration or reliability, safety margins, and state-of-the-art fabrication techniques. Consideration will be given to all materials finishes, coatings, etc., used in this assembly which might contribute to excessive outgassing.

3.4 Deviations

NASA/Langley shall be responsible for the approval of any deviations to this specification.

3.5 Weight

The weight of the umbilical subsystem shall be minimized, consistent with the requirements of this specification.

3.6 Envelope and Installation Details

The configuration, dimensions, and installation details of the umbilical assembly shall be as shown on drawings 113C8797, 253E551, 201R801 and the test fixture on drawing 101D1344.

3.7 Umbilical Assembly Performance Requirements

3.7.1 Pressure Drop

The differential pressure between the inlet and outlet of the oxygen and coolant lines shall be limited to the following values which include both halves of the quick disconnect:

PART NO.	LINE	P	FLOW @ UMBILICAL INLET
P1	O_2	44" H_2O	11.5 CFM @ 19.7 PSIA
	Coolant	2.0 PSI	0.5 GPM
P2	O_2	15.0" H_2O	11.5 CFM @ 19.7 PSIA
	Coolant	0.55 PSI	0.5
P3	O_2	11.5" H_2O	11.5 CFM @ 19.7 PSIA
	Coolant	0.37 PSI	0.5 GPM

3.7.2 Leakage

The external leakage shall not exceed the following values for the umbilical assembly.

PART NO.	LINE	PRESSURE	LEAKAGE
P1	O_2	15.0 PSIG	30 scc/hr.
	Coolant	21.0 PSIG	20 scc/hr.
P2	O_2	15.0 PSIG	20 scc/hr.
	Coolant	21.0 PSIG	10 scc/hr.
P3	O_2	15.0 PSIG	20 scc/hr.
	Coolant	21.0 PSIG	10 scc/hr.

3.7.3 Working Pressure

The umbilical assembly shall operate within the requirements of this specification with the oxygen lines pressurized to 15.0 PSID and the coolant lines pressurized to 21.0 PSID.

3.7.4 Working Temperature

The umbilical assembly shall meet the requirements of this specification when subjected to temperatures of 55°F to 300°F. Maximum temperatures shall be associated with time of exposure as follows:

300°F for one (1) minute

200°F for five (5) minutes

3.7.5 Non-Working Temperature

The umbilical assembly shall be capable of continuous exposure to 0°F and 150°F with no degradation in performance when exposed to the leakage requirements of Paragraph 3.7.2.

3.7.6 Flexibility

The umbilical assembly shall perform within the requirements of this specification when it is bent to a radius of 6 feet. The assembly shall be designed for maximum flexibility. Flexual capability shall allow the umbilical to be bent 180° to an approximate diameter of 12 feet with a maximum force of 20 pounds when umbilical oxygen is pressurized to 15.0 PSID.

3.7.7 Proof Pressure

The umbilical assembly shall operate within the requirements of this specification after exposing the oxygen lines to 22.5 PSIG and the coolant lines to 31.5 PSIG.

3.7.8 Tensile Strength

The tensile strength of the umbilical shall be a minimum of two hundred pounds when tested at room temperature.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Cleanliness

In order to insure a contamination level that is acceptable for breathing oxygen systems, the lines shall be cleaned and tested utilizing the procedures outlined for oxygen equipment in MSFC-SPEC-164.

All components making up this assembly shall be visually examined for evidence of corrosion products, metal chips, burrs, feather edges, grease, paint, or other contamination which constitutes a functional hazard to the system. Such contamination shall be cause for out rejection. Cleaned parts shall be stored in plastic bags or containers which are equally clean.

4.1.1 Procedures

The interior of the oxygen hose shall be cleaned by passing a nylon brush through the hose a minimum number of 25 times utilizing an 0.5% detergent and water solution at a temperature of 125 $\pm 10^{o}$F. The interior of the hose shall then be flushed with demineralized water at room temperature for a minimum period of 5 minutes. The hose will be vacuum dried with a prefiltered drying gas (maximum 100 micron level with hydrocarbon level below 3 PPM).

A trichloroethylene (Federal Specification O-T-634) flush will be utilized for the test fluid with the effluent analyzed to the requirements of Table 1. Failure to meet these requirements shall be considered cause for reflushing or re-cleaning and re-inspection.

TABLE 1

Cleanliness Levels Required For Final Solvent Rinse

Maximum Filterable Solids (1) (2) (3)

2 mg per square foot of surface area

Maximum Known Volatile Residue (NVR)

1 mg per square foot of surface area

Maximum Permissible Particles Including Fibers

0 - 175	Unlimited
175 - 350	30
350 - 500	2
Over 500	0

(1) Maximum non-filterable solids are the solids which will be retained on an HA or AA millipore filter or equivalent.

(2) The amount of final rinse fluid will be based on the use of 200 ml per square foot of surface area.

(3) The flushing times shall be a minimum of 5 minutes.

4.2 Materials

The materials used in this equipment shall be of high quality, functionally suited for this application, and shall meet the applicable specifications listed in Section 2.0 of this specification.

4.3 Workmanship

Workmanship shall be in accordance with high quality spacecraft manufacturing practice. Quality Control shall be in accordance with QCS-100-0 and MIL-Q-9858.

4.4 Design Verification Test

The following tests are designed to prove out the design, materials, and fabrication techniques utilized in the manufacture of prime umbilical assemblies.

4.4.1 Pressure Drop Test

4.4.1.1 Oxygen Line

The pressure drop through a 55 foot long oxygen line shall be tested to determine compliance with Paragraph 3.7.1 of this specification. The pressure drop shall be checked by flowing 11.5 CFM of air through the oxygen line utilizing piezometer rings at the inlet of a straight run. The ratio of oxygen and air densities shall be utilized in converting air pressure drop to oxygen pressure drop.

4.4.1.2 Coolant Line

The pressure drop through a 55 foot long coolant line shall be tested to determine compliance with Paragraph 3.7.1 of this specification. The pressure drop shall be checked by flowing 0.5 gallon per minute of a 60% water - 40% glycol, by weight, mixture through the coolant line. Pressure taps at the inlet and outlet shall be utilized in determining the pressure loss through the system.

4.4.2 Burst Pressure Test

4.4.2.1 Oxygen Line

A burst pressure test shall be conducted on a ten foot section of oxygen line by increasing the internal pressure to 30 PSIG and holding for a period of three minutes. The hose must not show evidence of rupture. At the conclusion of the above test pressure will be increased until rupture occurs.

4.4.2.2 Coolant Line

A burst pressure test shall be conducted on a ten foot section of coolant line by increasing the internal pressure to 42 PSIG and holding for a period of three minutes. The tubing must not show evidence of rupture. At the conclusion of the above test pressure will be increased until rupture occurs.

4.4.3 High Temperature Test

4.4.3.1 Oxygen Line

A high temperature test shall be performed by mounting a section of oxygen hose in a temperature chamber. A working pressure of 15.0 PSIG shall be applied internally and the pressure raised to 200° F and held for five minutes. The temperature shall then be increased to 300°F and held for one minute. At the conclusion of the high temperature test the hose shall be examined for evidence of failure.

4.4.3.2 Coolant Line

A high temperature test shall be performed on the coolant line by mounting a section in a temperature chamber. A working pressure of 21.0 PSIG shall be applied internally and the pressure raised to 200°F and held for five minutes. The temperature shall then be increased to 300°F and held for one minute. At the conclusion of the high temperature test the tubing shall be examined for evidence of failure.

4.5 Acceptance Test

4.5.1 Examination of Product

The umbilical assembly and/or test fixture shall be examined to determine compliance with the applicable drawings and all requirements of this specification.

4.5.2 Assembly Acceptance Test

Each assembly shall be tested to and pass the following acceptance tests prior to shipment.

4.5.2.1 Leakage Test

4.5.2.1.1 Oxygen Line

The oxygen lines shall be pressurized with oxygen to 15.0 PSIG utilizing the umbilical test fixture drawing 101D1344. Over a period of ten (10) hours the pressure shall not decay more than 0.7" Hg. Barometer and temperature readings shall be taken at the start and finish of the test for calibration adjustment.

4.5.3.1. Coolant Line

The coolant lines shall be pressurized with air to 21.0 PSIG utilizing the umbilical test fixture drawing 101D1344. Over a period of ten (10) hours the pressure shall not decay more than 1.0" Hg. Barometer and temperature readings shall be taken at the beginning and end of the test for calibration adjustment.

4.5.2.2 Continuity Test

A continuity test will be performed on each circuit of the umbilical assembly. A voltage less than 5 volts, commercial frequency, will be applied between each pin of the connector. Evidence of continuity shall be evidenced at the connector pins on the other end of the umbilical.

4.5.2.3 Coupling Engagement

The umbilical coupling half of the redundant (WYE) coupling halves shall be engaged utilizing a maximum force of forty-five (45) pounds. This test shall be conducted on both of the redundant (WYE) coupling halves.

5.0 PREPARATION FOR DELIVERY

The umbilical assemblies shall be packaged in a manner which will provide adequate protection against deterioration and damage resulting from handling, shipment, and storage.

The assembly shall be preserved and packaged in accordance with MIL-P-116D. Packages shall be packed in exterior type MIL approved containers in a manner which will insure safe transportation to point of delivery.

APPENDIX D

BIOINSTRUMENTATION DESIGN CONSIDERATIONS

BACKGROUND

The safety of the occupants of the Langley manned space chamber is of paramount importance, consequently indication of any significant medical or physiological difficulty on the part of the occupant shall be cause for test abort. By the same token any difficulty or injury that does occur to the occupant will require proper treatment immediately after the occupant can be reached by the medical personnel. Proper treatment depends upon an accurate diagnosis and an understanding of the nature of the difficulty or injury. Experimental test subjects may develop medical or surgical emergencies independent of chamber operation (i.e., heart attack, stroke, appendicitis, mechanical trauma, etc.). Peculiar behavior and discomfort leading to possible unconsciousness and/or convulsions may be the result of the above or from hazards more generally associated with chamber operation (i.e., hypoxia, hyperventilation, psychogenic reactions, "bends", rapid decompression, general stress, etc.). Additional considerations associated with man-rating the chamber are the speed with which corrective action must be taken, in the case of a required test abort, and, on the other hand, possible unnecessary interruption of an expensive, time consuming test program.

For the above reasons, an "in-vivo" monitoring system of the man in his spacesuit must be incorporated which will provide a real time indication of the health of the chamber occupant.

The monitoring system shall consist of a minimum amount of equipment while at the same time shall provide a medical monitor with enough information such that he can determine the necessity of a test abort.

The parameters selected for monitoring the test subject are listed in Table I.

TABLE I BIOMEDICAL PARAMETERS CHOSEN

Measured Parameter	Information Provided
1 - Deep Body Temperature 2 - Skin Temperature	Body heat balance provides a measure of the general well-being of the test subject
3 - Heart Potential (ECG) and Heart Rate	Indicates heart rate, presence of fibrilation, tachycardia, brochycardia, heart block, neorginal anoxia
4 - Respiration Rate	Rate of chest movement or breathing rate (breaths/min.)
5 - Suit parameters a) Suit inlet temperature b) Suit outlet temperature c) Suit pressure	Provides information on the performance of all the mechanical suit-support equipment (i.e., ECS and umbilical) on the suit

All of the above parameters are easily monitored, and will provide meaningful data in that qualitative decisions concerning the abort or continuation of the test can be made on the basis of this data. The monitoring which will be referred to as the Bio-Medical monitoring system shall provide both an indication of the occupants general health and an indication of the status of a number of specific medical variables (e.g., ECG). The equipment providing this information will be referred to as the bio-instrumentation system. The bioinstrumentation system includes the sensor, signal conditioners and harness detail. The Bio-Medical monitoring system shall measure the variables in Table II.

TABLE II BIO-MEDICAL VARIABLES TO BE MEASURED

Signal Variable	Source Signal Range
Deep Body Temperature	93 - 107°F
Skin Temperature	80 - 120°F
Heart Potential (ECG) and heart rate	± 3 mv, 0.2 - 300 cps 0 - 300 beat/min.
Respiration Rate	0 - 60 beats/min.
Suit Pressure	0 - 25 psia
Suit Inlet Temperature	50 - 80°F
Suit Outlet Temperature	65 - 125°F

DISCUSSION

DEEP BODY TEMPERATURE

There are two locations which indicate deep body temperature without breaking the skin. They are in the buccal cavity (mouth) and the anus. A third possible location, in the ear shall not be considered due to its lack of acceptance to date by the medical profession.

The anus is preferred as the site for the measurement of deep body temperature, since it can provide a continuous readout of temperature over a period of from five to eight hours, without being affected by such artifacts as eating, drinking, coughing, and most importantly, talking.

The sensor chosen for this application is a thermistor having a flexible housing.

SKIN TEMPERATURE

There are an infinite number of possible locations for the skin temperature probe. However, the location of the skin temperature should be so located that it:

a) Generates a minimum of discomfort for the subject,

b) Is compatible with the suit,

c) Provides a reproducible output.

d) Is compatible with the anticipated activity of the subject

A position on the frontal body area corresponding to just beneath the sternum satisfies the criteria mentioned above test. The probe used here shall be attached to the subject by means of 1½" square adhesive bandages.

ELECTROCARDIOGRAM (ECG)

As shown on Table II, the output of the ECG is a relatively low electrical signal. Movement of the subject can cause two types of signal noise:

1. That created by skeletal muscle potentials
2. That resulting from the disturbance of the contacts of the electrodes on the body, thus changing the coupling resistance.

The above artifacts can be minimized by inducing the subject to remain as still as possible, and/or by attaching the electrodes in a manner so as to prevent their movement. Since it is expected that the subject will be making some extensive motions in order to evaluate different space suits, it becomes necessary to locate the electrodes in relatively non-moving areas. It has been shown that for optimum electrode placement for minimum noise generation in a working situtation, electrodes should be placed bilaterally in the midaxillary line at the level of the fourth (or fifth) intercostal space. This permits all of the postures, positions, and movements except for rather violent adduction or abduction of the arms. The contraction of the intercostal respiratory muscles in extreme respiratory exertion can generate some movement artifacts but has not been shown to be too troublesome.

An alternate location of the electrodes would be to place them along the sternal axis at the M-X locations (manubrium, xiphoid).

The ECG signals will be amplified by a small preamplifier worn by the subject. The preamplifier will amplify the ECG signal to 100 mv for full scale input to the ECG readout module.

The ECG electrodes shall make use of a standard ECG electrode jelly.

HEART RATE

The heart rate will be generated from information provided by the ECG signal. A pulse rate module will sense the R-peaks of the electrocardiogram and average the information for the preceeding three or four beats, thereby providing an indication of the average heart rate. The heart rate (or pulse rate) will be continuously displayed with a range of from 0 to 300 beats per minute. It is desirable for an adjustable blinking light and audible tone to be mounted on the readout panel which shall respond to each breathing cycle.

RESPIRATION RATE

The respiration rate readout module senses and displays respiration rate utilizing either nasal, oronasal or chest band type interchangeable sensors. The nasal type sensor making use of a nose clip is the preferred method for reading respiration rate. The electrode is a nasal thermistor utilizing a flexible housing. It is desirable for a blinking light to be mounted on the readout module which shall correspond to each breathing cycle.

SUIT PRESSURE

In the strictest definition of the word, the biomedical instrumentation system should not include suit pressure or suit temperature. However, these parameters will have a direct effect on the well being of the test subject, furthermore the suit parameters will be affected to a great degree by the test subject. It is for these reasons that the suit parameters are considered to be part of the bioinstrumentation system.

In order to get a proper indication of suit pressure, the pressure sensor should be located such that the free volume being measured has minimum distortion due to walking or test subject motion. For this reason, the helmet area of the suit was chosen as the site for sensing pressure. A small flexible .25" plastic tube shall be taped to the back of the subjects head and run down his chest to attach to the transducer which is carried by the subject in a small junction box. The pressure transducer has overall dimensions of .88 inches in diameter by 1.83 inches long. The pressure transducer shall be extremely rugged so that jarring or motion will not generate false outputs. No warmup or stabilization time shall be required for these units.

If desired the pressure transducer can be mounted directly in the helmet area. In order to mount the transducer in the helmet, a fitting will have to be provided in the helmet to receive the pressure transducer.

There is a strong possibility that respiratory artifacts will be observed on the pressure readout and as a consequence, an indication of respiration rate will show on the total suit pressure readout.

SUIT TEMPERATURES, INLET AND OUTLET

Location of the suit inlet and outlet temperature probes will be dependent on the design of the individual space suit being tested. Responsibility of locating representative sites for location of the suit temperature sensors will be the responsibility of NASA/Langley Research Center (LRC). Both inlet and outlet temperature probes shall be thermistors. Having a flexible housing and approximate dimensions of .150 inches in diameter by .1875 inches long.

VOICE COMMUNICATION

Voice communication shall be considered as part of the bioinstrumentation system for the purposes of this study. This decision is based on the following:

1) The voice channel will provide gross information indicating the physiological state of the subject. Information such as "I'm feeling fine", or "everything's A-OK", can provide a measure of assurance that the test subject is in good health. This information should be evaluated with respect to the other inputs but can be used as a backup in case of questionable meter readings.
2) The voice channel shall be carried through the junction box (see the section on INCREASED CAPABILITY). Furthermore if increased capability is desired the voice channel could be carried over the ECG channel (see section on INCREASED CAPABILITY).

Voice communication to and from the subject can be handled using a conventional throat microphone and audio system. One cable for voice in and one for voice out would be required. A two station master with six remotes, of conventional voice quality is estimated as the requirement. Capability for slave station override from any of the master stations should also be provided.

INCREASED CAPABILITY

Conversion to RF links at a later date as a back-up would be possible by using each signal conditioner in a wireless system. The ECG channel could also be used for the audio channel because of its broad response band.

A typical Bioinstrumentation System using RF is described below.

TABLE III

TYPICAL PHYSIOLOGICAL FUNCTIONS

SPECIFICATIONS	ECG	RESPIRATION	TEMPERATURE
Input Signal Range Full Scale	3 millivolts	5000 ohm probe	93°F to 107°F
Frequency Response	0.15 to 3000 cps	depends on probe	up to 100 cps
Transmitter Length	2.08 in.	2.08 in.	2.08 in.
Transmitter Weight Incl. Battery	2.0 oz.	2.0 oz.	2.0 oz.
Typical Sensing Transducers	Ag. Ag Cl surface electrodes or silver implants	nasal clip, chest band nasal mask, oronasal mask or .020 inch diameter bead	stainless, epoxy, vinyl, or .030 in. diameter bead

All systems shall be fully transistorized and utilize state-of-the-art crystal controlled transmitters and receivers which require no tuning or frequency adjustment.

Narrow band VHF frequencies shall be used, thereby eliminating interference from X-ray, ultrasound, diathermy, flourescent lights and other electrical apparatus. The above systems can be used for the transmission of other data within the indicated input ranges. Each transmitter shall include input signal conditioner, transmitter, and snap in battery capable of 10 to 15 hours operation with rechargeable batteries and mercury batteries of extended life being available. The broadcast range of such systems is normally 200 feet with extended ranges of up to one mile being available. Receivers shall operate on 110-120 volt 50 cycle AC power. A $\pm$100 millivolt output corresponding to the full scale input to the transmitter can be provided for recording on standard physiological recorders. Receiver weight shall be approximately 5 pounds.

Capability for adding additional sensors besides those chosen shall be provided by this system as indicated in the general criteria section.

If it is shown at some future date that there is a requirement for storing the biomedical information on magnetic tape then the system should provide this capability without any design or equipment changes necessary.

GENERAL CRITERIA

The following general criteria and detail information supplements the subject discussions above.

1. Signal conditioners for ECG and Respiration shall measure approximately 1/2 x 1/2 x 1-1/2 inches and weigh about two ounces including connectors.
2. The operating voltage of each signal conditioner shall be 12 V DC at a current of 5 ma or less. The signal conditioner output voltage shall be +250 mv for full scale input from the electrodes or sensor.

3. All the sensor leads shall terminate in a junction box which is carried or worn on the person of the test subject. A desirable method and location for carrying the junction box is to insert it in a breast pocket which is sewn into the subject's shirt.

The junction box shall be approximately the size of a cirgarett pack, and shall have a number of input and output spares to provide for future sensor additions.

The junction box shall house the necessary preamplifiers and pressure transducer with room left in the junction for an additional preamplifier, if it is found desirable to add one at some future date.

The signal jumper cable between the junction box and the suit electrical outlet shall vary in length and design with different suits, consequently the design and fabrication of the jumper cable between the junction box and the suit electrical outlet and the external cable between the suit electrical outlet and umbilical connector shall be the responsibility of LRC.

BIOINSTRUMENTATION SYSTEM SELECTION

The method for determining the proposed bioinstrumentation system package was to:

a) Solicit quotes from all known vendors in the bioinstrumentation field.

b) Judge all the proposals with respect to some predetermined criteria.

c) Discuss refinements and/or suggested modifications with the chosen vendor.

The method employed to secure meaningful quotes from the nineteen vendors was to generate a preliminary specification for the bioinstrumentation system. This specification was based on the general bioinstrumentation

information determined relatively early in the program. As such, it bears little resemblance to the system as finally determined. However, it served as a method for generating vendor information which in turn was evaluated on an equitable basis. The preliminary specification as sent out for a "Request for Proposal" (RFP) is shown below.

PRELIMINARY SPECIFICATION FOR BIOINSTRUMENTATION - SYSTEM STUDY

Bioinstrumentation system is to include the sensor, signal conditioners, readout and harness details. System is to monitor

Signal Variable	Source Signal Range & Tolerance
Deep Body Temperature	95 - 105 $\pm$ 1°F
Skin Temperature	80 - 120 $\pm$ 1°F
Heart Potential (ECG) and heart rate	0 - 5 mv .2 - 100 cps
Respiration (e.g. impedence pneumograph)	0 - 100 mv 0 - 100 beats/min.
Suit Pressure	0 to 25 $\pm$ 1% psia
Suit Inlet Temperature	50 to 80 $\pm$1°F
Suit Outlet Temperature	65 to 120 $\pm$1°F
Voice Communication	

Bio-signals are to be transmitted to a readout panel thru fifty-five feet of umbilical harness. Signal conditioners are to be carried on man by means of a vest type garment thereby amplifying bio-signals before transmittal thru umbilical. The following typifies the information required.

Level and characteristics of output signal from signal conditioners

Type of suggested sensor (manufacturer and catalogue number)

Type of suggested readout (manufacturer and catalogue number)

Type harness shielding required

Method of handling shielding thru connectors

Method of tying power and signal leads thru the same connector

Weight of signal conditioners and vest

Size of suit temperature sensors

Size of pressure sensor

Methods of bonding or attaching suit sensors (both pressure and temperature) to the suit (pressure sensor is to be helmet-mounted)

Cost

The preliminary specification was sent to the following nineteen companies. The nineteen companies were chosen from reference 8. Only those companies marked with an asterisk answered the RFP in a satisfactory manner.

VENDORS SOLICITED

Bionic Instruments *
221 Rockhill Rd.
Bala Cynwyd, Pa.

Biocom, Inc. *
5883 Blackwelder St.
Culver City, California

Cardel Laboratories
17 Zoranne Dr.
E. Northport, New York

Consolidated Electrodynamics Corp.
350 Sierra Madre Villa
Pasadena, California

Ensco Inc.
3100 Eldredge St.
Salt Lake City 15, Utah

Gulton Ind. Inc. *
212 Durham Ave.
Methchen, New Jersey

Instrumentation & Control Systems, Inc.
686 Fairview
Elmhurst, Illinois

Jaeger Laboratories
550 W. Spring St.
Columbus 16, Ohio

Kenelco Inc.
5638 Bankfield Ave.
Culver City, California

Mennen Greatbach Electronics, Inc. *
10440 Main Street
Clarence, New York 14031

Par Products Corp.
602 Colorado Ave.
Santa Monica, California

Physiological Electronics, Inc.
P. O. Box 9831
Chevy Chase, Maryland

Sanborn Co.
175 Wyman St.
Waltham 54, Mass.

Sumanetics, Inc.
7460 Girard Ave.
LaJolla, California

Sonamedic Corp.
245 Old Hook Road
Westwood, New Jersey

Spacelabs Inc. *
15521 Lanark Street
Van Nuys, California

Telemedics Div., Vector Mfg. Co., Inc. *
Southampton, Penna.

Universal Microwave Corp.
160 N. Fair Oaks Avenue
Pasadena, California

5. Size

    A. Transducer

    B. Signal Conditioners

    C. Readout

6. Weight

    A. Transducer

    B. Signal Conditioner

    C. Readouts

7. Cost and Delivery

AREAS OF VALUATION	BIOCOM INC.	BIONICS
1. Equipment System Design	Design of specialty hardware to fit customer requirements. Primarily for unusual or stringent requirements requiring one of a kind type of hardware.	Design hardwar requirer for unu requirer one of hardwar
A. Comments	Man-pack signal cond. uses rack mounted amplifiers and power supply. Uses line computer for readout and evaluation.	Uses im pneumog respira All sig amplifi mounted
2. Equipment Availability		
A. Ease of Hardware Addition		
1) Electrodes	Uses standard electrodes manufactured by Yellow Springs.	Uses st trodes by Yell

D. BIOINSTRUMENTATION VENDOR EVALUATION

INST.	GULTON MEDICAL INST.	MENNEN GREATBA
)f specialty : to fit customer ients. Primarily sual or stringent ients requiring a kind type of :.	Each physiological measurement utilizes a self-contained independent module, which can be operated by itself or rack mounted in various groupings. Standard modules are available for all parameters required by study.	Design of speci ware to fit cus quirements. Pr for unusual or requirements re one of a kind t hardware.
)edance raph to monitor :ion rate. nals are ed by vest amplifier.	All readout modules are of a standard size which make rack mounting, modification, and relocation relatively simple. Signal conditioning are standard and have provision for telemetry.	
andard elec- manufactured ow Springs	Uses standard off-the-shelf Ag-AgCl electrodes which are manufactured by Gulton. Pressure sensor is also manufactured by Gulton.	Uses standard o shelf Ag-AgCl e which are proba chased and Yell Springs thermis

H ELEC.	SPACELABS	TELEMEDICS GROUP (VECTOR)
alty hard-tomer re-imarily stringent quiring ype of	Design of specialty hardware to fit customer requirements. Primarily for unusual or stringent requirements requiring one of a kind type of hardware.	Uses FM multiplex to transmit physiological signals over single hardwire. Standard signal conditioners, demonstrators, and meter indicators are digital readout type.
	Specializes in flight type hardware. Resulting in minimum space and weight. Uses impedance pneumograph for respiration rate sensor.	Novel idea of using FM multiplex to reduce hardwire requirements in umbilical; however, multiplex complicates system and makes equipment heavier at both ends.
ff-the-lectrodes bly pur-ow tors.	Uses standard electrodes manufactured by Yellow Springs. No information on pressure sensor	Uses standard Yellow Springs thermistors. Statham pressure gauge, telemedics ECG sensor.

3

AREAS OF VALUATION	BIOCOM INC.	BIONICS INST.
2) Signal Cond.	Would require fabrication of additional specialty electronic equipment or modification of previously designed specialty equipment.	Would require fabrication of additional specialty electronic equipment or modification of previously designed specialty equipment.
3) Readouts	No information; would probably use standard meters panel mounted. Would then require modification of readout panel by punching holes, etc.	Uses standard panel mounted meters. System modification would necessitate modification of read out panel by punchin holes, etc.
B. Ease of modification		
1) Electrodes	Uses standard electrodes manufactured by Yellow Springs.	Uses standard electrodes manufactured by Yellow Springs.
2) Signal Cond.	Would require fabrication of additional specialty electronic equipment or modification or previously designed specialty equipment.	Would require fabrication of additional specialty electronic equipment or modification or previously designed specialty equipment.

GULTON MEDICAL INST.	MENNEN GREATBACH ELEC.
Standard, and modularized signal conditioners, will allow for ease of signal conditioner addition.	Standard and modularized signal conditioners, wil allow for ease of signal conditioner addition.
Standardized modular readouts (or indicators) can be easily added to system by simply inserting module in rack.	No information. Would probably use standard meters panel mounted. Would then require modification of readout panel by punching holes, etc.
Uses standard off-the-shelf electrodes which are manufactured by Gulton.	Uses standard off-the-shelf Ag-AgCl electrodes which are probably purchased, and Yellow Springs thermistors.
Standard, and modularized signal conditioners, will allow for ease of signal conditioner addition.	Standard, and modularized signal conditioners will allow for ease of signal conditioner addition.

SPACELABS INC.	TELEMEDICS GROUP (VECTOR)
Standard, and modularized signal conditioners, will allow for ease of signal conditioner addition.	Standard and modularized signal conditioners will allow for ease of signal conditioner addition.
No information.	Would require addition demodulation equipment.
Uses standard electrodes manufactured by Yellow Springs. No information on pressure sensor.	Uses standard Yellow Springs thermistors. Statham pressure gauge, Telemedics ECG Sensor.
Standard, and modularized signal conditioners will allow for ease of signal conditioner addition.	Standard, and modularized signal conditioners will allow for ease of signal conditioner addition.

3

AREAS OF VALUATION	BIOCOM INC.	BIONICS INST.
3) Readouts	No information. Would probably use standard meters panel mounted. Would then require modification of readout panel punching.	Use standard panel mounted meters. System modificatio would necessitate modification of readout to panel by punching holes, etc.
C. Ease of replacement (or spare)		
1) Electrodes	Use standard electrodes manufactured by Yellow Springs.	Use standard elect manufactured by Yellow Springs.
2) Signal Cond.	Would require fabrication of additional specialty electronic equipment or modification of previously designed specialty equipment.	Would require fabr cation of additiona specialty electron equipment or modif cation of previous designed specialty equipment.
3) Readouts	No information. Would probably use standard meters panel mounted. Would then require modification of readout panel - punching holes, etc.	Uses standard pane mounted meters. S modification would necessitate modifi cation of readout panel - punching h etc.
3. Past Experience/Use	Delivered two hardwire physiological data acquisition systems to Lockheed Missiles	In last two years built two patient monitoring systems One for Penna. Hos pital in Phila. The other for Jefferson Medical College in Phila.

	GULTON MEDICAL INST.	MENNEN GREATBACH ELEC.
n	Standardized modular readouts (or indicators) can be easily added to system by simply inserting module in rack.	Use Standard panel mounted meters. System modification would necessitate modification of readout to panel by punching holes, etc.
rodes	Uses standard off-the-shelf electrodes which are manufactured by Gulton.	Uses standard off-the-shelf Ag-AgCl electrodes which are probably purchased, and Yellow Springs thermistors.
i- al ic i- ly	Standardized modular readouts (or indicators) can be easily added to system by simply inserting module into rack.	No information. Would probably use standard meters panel mounted. Would then require modification of readout panel - punching holes, etc.
l ystem - oles,	Standardized modular readouts (or indicators) can be easily added to system by simply inserting module into rack.	No information. Would probably use standard meters panel mounted. Would then require modification of readout panel - punching holes, etc.
. -	Provided physiological monitoring system similar to type required by study, for G.E. terranaut tests. Provided physiological readout systems for many hospitals, did not receive specifics of hospital experience.	No information.

SPACELABS INS.	TELEMEDICS GROUP (VECTOR)
No information.	Since readouts are digital, modification of one sensor for another should not affect readout.
Uses standard electrodes which are manufactured by Yellow Springs. No information on pressure sensor.	Uses standard Yellow Springs thermistors. Statham pressure gauge, Telemedics ECG Sensor.
No information. Would probably use standard meters panel mounted. Would then require modification of readout panel - punching holes, etc.	Since readouts are digital, modification of one sensor for another should not affect readout.
No information. Would probably use standard meters panel mounted. Would then require modification of readout panel - punching holes, etc.	Since readouts are digital, modification of one sensor for another should not affect readout.
Flight qualified physiological off-the-shelf hardware for Gemini and Apollo programs. Providing Grumman with LEM physiological monitoring system, but was not sent any info, in regard to this system.	Much experience in hospital physiological monitoring systems; no specifics provided.

AREAS OF VALUATION	BIOCOM INC.	BIONICS INST.
A) Comments		
4. Power Source	No information. (Uses power supply)	No information.
5. Size		
A) Transducer	No information - assume standard size.	Temperature othe skin 1/8" dia. x Skin temp. 3/16" 1/8" ECG 1" dia. x 1/ Press. 1" dia. x long.
B) Signal conditioners	Man-pack contained in extruded aluminum package 1" x 2.5" x 6".	No information.
C) Readout	No information on indicators. Six rack mounted line amplifiers are required. Each of which is 3" high x 19" wide. (A 0-10 V meter is provided with each of the line amplifiers).	No specific info mation. Probably standard meters, cated in panel.

/

	GULTON MEDICAL INST.	MENNEN GREATBACH ELECT.
	Proven experience with modularized concept in which each readout is self-contained; provides great flexibility, in readout location relative position, arrangement, trouble-shooting, etc.	
	110 - 120 V 60 cycles AC to readouts.	No information.
r than 6½" dia. x 4" 1"	No information - assume standard size.	Standard size. ECG 1/2" dia. x 1/8" thick.
	All signal conditioners and pressure TXDCR are mounted in a container 1 x 2 x 4.	No information.
r- uses lo-	Each readout module is a standard 4 inches wide x 7.5 inches high by 13 inches wide.	No specific information. Probably uses standard meters, located in panel.

SPACELABS INC.	TELEMEDICS GROUP (VECTOR)
No information	Two 8.4 volt batteries connected in series - worn by subject.
No information - assume standard size. Use Yellow Springs thermistor.	No information - assume standard size. Use Yellow Springs thermistors.
Each signal cond. is approximately .4 x 1.5 x 2.3.	Each signal conditioner is approximately 4½" x 1-3/8" x 1".
No specific information. Probably uses standard meters, located in panel.	No information - standard digital readout.

AREAS OF VALUATION	BIOCOM INC.	BIONICS INST
6. Weight		
A) Transducer	No information - assume weight for standard TXDCR.	No informati Assume weigh standard TXD
B) Signal Conditioner	No information.	1 - 1.5 poun all signal c in (man-pack
C) Readouts	No information.	No informati
7. Cost and Delivery	Approximately $8,000.00 without readouts.	System cost Delivery fro of order is days.

	GULTON MEDICAL INST.	MENNEN GREATBACH ELECT
on. t for CR.	No information. Assume weight for standard TXDCR.	No information. Assume weight for standard TXDCR.
ds for onditioners).	0.5 pound for subject mounted signal cond. pkg.	No information on subje carried signal conditioners.
on.	ECG - 5 lbs. Respiration rate - 6 lbs. Heart Rate - 6 lbs. Temperature - 5 lbs.	No information.
$13,500. m receipt. about 120	System cost $9,900 without communication net design. Approximately $10,500 depending on net design. Delivery from receipt of order is less than 60 days.	System cost without communication net $13,492. Delivery from receipt of order is 70 days.

2

	SPACE LABS	TELEMEDICS GROUP (VECTOR)
	No information. Assume weight for standard TXDCR.	No information - assume weight for standard TXDCR.
ct	Each signal conditioner weighs approximately 50 grams.	Each signal conditioner weighs 3.5 ounces.
	No information.	Total readout unit 45 pounds.
	No information.	System cost with communication is approximately $23,000.00; delivery is approximately 120 days.

3

SUMMARY OF BIOINSTRUMENTATION VENDOR EVALUATION AND VENDOR CHOICE

The system as proposed by Gulton Medical Electronics has been chosen for the bioinstrumentation system on the NASA/Langley man-rating study for the following reasons:

1. Gulton is the only company of the seven companies that provided proposals to G.E. that has a complete line of off-the-shelf equipment in the specific area as defined by our study. Furthermore, Gulton is the only company that manufactures the entire line of bioinstrumentation as defined by our study. This includes the electrodes, signal conditioners and readouts. The advantage here is that only one source is required for technical information, advice, repairs, etc.

2. The concept of fabricating the readouts as self-contained uniformed size, independent modules offers many advantages;

   a) If desired readouts can be simply rearranged in the rack.

   b) The individual modules can be used in different areas for check-out, troubleshoot, replacement, etc., by simply removing the module from the rack and plugging the module into the nearest 100V - 60 cycle outlet.

   c) Future modules can be purchased and rack mounted in the same location without need for extensive modification or planning.

3. Gulton proposes small preamplifiers to be carried by subject with the signal to be further amplified at the readout by the standard readout amplifiers. This results in a relatively small and light amount of hardware to be carried by the subject. All other vendors propose that the subject carry amplifiers which are heavier than the Gulton arrangement.

One proposal suggested the use of FM multiplex in order to reduce the number of required cables in the umbilical to one. Although this has some merit, the additional equipment required at both the subject and readout ends of the umbilical; and the decreased reliability, make this an impractical approach.

4. A number of proposals indicated experience and hardware qualified for flight. This is unnecessary and costly. On the other hand, Gulton has demonstrated much usage by hospitals of their requipment in either multiple or single module arrangements.

5. Modules proposed are standard off-the-sheld items, consequently, cost and delivery time are at a minimum (less than any of the other proposals).

SVS 7434

BIO-INSTRUMENTATION SYSTEM DESIGN SPECIFICATION

1.0 SCOPE

1.1 Scope - This specification establishes the requirements for the design, fabrication, testing and preparation for delivery of the Bio-Instrumentation to be used by two (2) suited occupants of the NASA-Langley Research Center (LRC). The Bio-instrumentation system is to also be used by two unsuited occupant (in a "shirtsleeve" environment) in the LRC Space chamber airlock. All subjects shall be monitored at the Medical Console in order to determine their general well-being and physiological state. Personnel manning the Medical Console shall then be continuously aware of the subjects medical and physiological state.

2.0 APPLICABLE DOCUMENTS

2.1 Government Documents - The following government documents of the issue listed, form a part of this specification to the extent specified herein.

Specifications

MIL-Q-5923	Quality Control Requirements, General
MIL-W-8160	Wiring, Guided Missile, Installation of

Standards

MIL-STD-129 C 10 Feb. 1961	Marking for Shipment and Storage
MIL-STD-130 B 24 April 1962	Idnetification, Marking of U.S. Military Property
MIL-STD-143 A 14 May 1963	Specification and Standards, Use of
MS-33586A 16 Dec. 1958	Metals, Definition of Dissimilar

2.2 Non-Government Documents - The following non-government documents of the issue in effect on the date of this specification or invitation for bids form a part of this specification to the extent specified herein.

General Electric Company - MSD - MOL Department

Drawings

201R803	Control Panel, Bio-Med/ECS Rescue #1 & #2
201R806	Biomedical Sensor Locations, Umbilical Harness and Coupler
2532553	Control Panel, Bio-med/ECS Test Subject

3.0 REQUIREMENTS

3.1 Bio-Instrumentation System Description - The Bio-Instrumentation System shall consist of all transducers, signal conditioners, display and alarm modules for sensing, amplifying, transmitting through a 100 foot long, 7 connector umbilical cord, continuously displaying, alarm monitoring and providing output voltages for recording the physiological variables shown in Table I. The Monitoring Console shall be made up of individual signal conditinning and alarm modules of standard size and configuration permitting simplified servicing of individual physiological functions, and later expansion or alteration of the functions being monitored.

Table I: Physiological Variables to Be Measured

Signal Variable	Range & Accuracy
Heart Rate & ECG	0-300 beats/minute ± 2 beats/minute
Deep Body Temperature	93-107°F ± 0.1°F
Skin Temperature	80-120°F ± .3°F
Respiration Rate	0-60 cycles/minute ± 1 cycle/minute
Suit Pressure	0-25 psia ± 0.5 PSI
Suit Inlet Temperature	50-80°F ±0.2°F
Suit Output Temperature	65-125°F ±0.5°F

3.2 Equipment Requirements - Table II shows all the bio-instrumentation electrical and system requirements.

3.2.1 Subsystem Requirements -

3.2.1.1 Heart Rate and ECG - A three lead clinical quality ECG shall be obtained from sternum electrodes of minimum size, weight, and encumbrane. The low level ECG signals shall be amplified in the Junction Box to levels and with suitable impedances for hard wire transmission through an umbilical cord up to 100 feet in length and including up to six intermediate connectors. The amplified ECG shall be connected to the Console ECG Module which shall provide a standardized output for recording on paper and/or magnetic tape. The ECG shall also be connected to the Console Heart Rate Module which shall permit setting High and Low Rate Limits, continuously indicate averaged heart rate and simultaneously give an audible and visual indication of each heart beat. The audible level shall be adjustable at the Console Heart Rate Module. No other front panel adjustments shall be required.

Transducer shall be Gulton M-11 or equivalent, Junction Box Signal Conditioner shall be Gulton M-284 ECG or equivalent, Display and Alarm Module shall be Gulton M-20453 or equivalent.

3.2.1.3 Deep Body Temperature - A small flexible, vinyl thermistor probe shall be used to measure rectal temperature. Output of the probe shall be connected to the Junction Box which shall act as an interconnection terminal only. No electronics are required. The probe's signal shall be of suitable output and impedance for hard wire transmission through the umbilical cord defined in Paragraph 3.2.1.1. Total line resistance variation shall cause errors not to exceed $0.1^{o}F$ in the measured range.

TABLE II BIOINSTRUMENTATION - SYSTEM REQUIREMENTS

	HEART RATE & ECG	DEEP BODY TEMPERATURE	SKIN TEMPERATURE	RESPIRATION RATE	SUIT PRESSURE	SUIT TEMPERATURE Inlet	SUIT TEMPERATURE Outlet	SPARES
RANGE OF MEASUREMENT	0-300 b/m	93 - 107°F	80 - 120°F	0-60 b/m	0-25 PSIA	50 - 80°F	65 - 125°F	
TRANSDUCER								
Location	sternum	rectum	sternum	nostril	helmet	inlet tube	outlet tube	
Probe Type	Ag-Ag-CL	thermistor	thermistor	thermistor	LVDT	thermistor	thermistor	
Quantity	3	1	1	1	1	1	1	
Size	0.75" dia x 0.13" tk	0.15" dia x 0.19" lg	0.25" dia x 0.10" tk	0.06" dia bead	0.06" dia tube to junction box	to suit	to suit	
Weight	2 GMS ea.	8 GMS	10 GMS	2 GMS	--	30 GMS	30 GMS	
Attachment	Blenderm	insert	Blenderm	nostril clip	--	thread	thread	
Signal Output	± 3 mv	5Ω/0.1°F	5Ω/0.1°F	4Ω/0.1°F	--	14Ω/0.1°F	7Ω/0.1°F	
Response	0.15 to 300 CPS	2 sec/°F	3 sec/°F	0.5 sec/°F	--	4 sec/°F	4 sec/°F	
GULTON PART NUMBER	M-11	M-20040	M-20060	M-32CB2A	P-100G (0.8" dia x 1.1"lg)	M-20090	M-20090	
TRANSDUCER TO JUNCTION BOX								
Cable Size	1 (#32) SH	2 (#26)	2 (#26)	2 (#26)	--	2 (#26)	2 (#26)	
Cable Length	18"	36"	18"	24"	24" tube	24"	26"	
Configuration	0.060" OD	0.088" OD	0.088" OD	0.088" OD	0.06" OD	0.088" OD	0.088" OD	
Attachment to Transducer	solder/epoxy	solder/epoxy	soler/epoxy	epoxy	luer fitting	solder/epoxy	solder/epoxy	
Cable Connector (Gulton Part No.)	C5P (3-REQD)	C5P	C5P	C5P	luer fitting	C5P	C5P	
JUNCTION BOX (GULTON # M-765)								
Signal Conditioner (yes/no)	yes	no	no	yes	yes	no	no	
Output Level	#250 mv			± 250 mv	± 250 mv			
Supply Voltage	12 VDC			12 VDC	12 VDC			
Power Required	60 mw			60 mw	200 mw			
Approximate Size of Circuit	½" x ½" x 1¼"			½" x ½" x 1¼"	½" x 1" x 1-5/8"			
Approximate Weight of Cufcuit	7 GMS			8 GMS	15 GMS			
Connector (from transducer) (Gulton Part #)	C5R1 (3-REQ'D)	C5R1 (float)	C5R1 (float)	C5R1	luer fitting	C5R1 (float	C5R1 (float	(5) C5R1
Connector (to umbilical)	← CANNON MD1-25 SL1 →							
GULTON PART NUMBER (CONDITIONER)	M-284 EMG	--	--	M-284 RESP	M-284 BP			
JUNCTION BOX TO UMBILICAL								
Connector on UMBILICAL	CANNON MD1-25PL1							
Pin Assignments: (later)	#1 #2 #3 #4 #5 #6 #7 #8 #9 #10 #11 #12 #13 #14 #15 #16 #17 #18 #19 #20 #21 #22 #23 #24 #25							
UMBILICAL CHORD								
Cable Length	100 ft	100 ft	100 ft	100 ft	100 ft	100 ft	100 ft	100 ft
Intermediate Connectors								
Cable Size	2(#21) SH	2(#21) SH	2(#21) SH	2(#21) SH	2(#21) SH	2 (#21) SH	2 (#21) SH	2x9 (#21) SH
Configuration	0.10 OD			0.10 OD				
GULTON PART NUMBER	TX 15214			TX 15214	TX 15214-2			
UMBILICAL TO DISPLAY MODULES								
Intermediate Connectors								
DISPLAY MODULES								
Meter Range/Increment	0-300/10 b/m	93-107/0.2°F	80-120/0.6°F	0-60/2 b/m	0-25/1 psi	50-80/0.4°F	65-125/1.0°F	
Display Accuracy	± 2 b/m (normal range)	± 0.4°F	± 0.3°F	± 1 b/m (normal range)	± 0.5 psi	± 0.2°F	± 0.5°F	
Output Level/Load	±100 mv/10k ECG 100 mv/10k rate	100 mv/10k	100 mv/10k	± 100mv/10k wave 100 mv/10k rate	100 mv/10k	100 mv/10k	100 mv/10k	
Output Accuracy	± 1%	± 1%	± 1%	± 1%	± 1%	± 1%	± 1%	
Limit Alarms (adjustable)	Low - High	Low - High	Low - High	Low--High	Low - High	Low - High	Low - High	
Input/Output Connector (rear)	Amphenol 26-159-16	26-159-16	26-159-16	26-159-16	26-159-16	26-159-16	26-159-16	(2)26-159-16
Front Panel Control	Audio volume, Mech. zero, reset	Mech. zero, reset	Mech. zero, reset	Mech zero, reset	Mech zero, reset	Mech zero, reset	Mech. zero, reset	
Front Panel Indicators	Blink light, Hi & Lo Alarm light	Hi & Lo Alarm Lights	Hi & Lo Alarm Lights	Hi & Lo Alarm Light Blink Light	Hi & Lo Alarm	Hi & Lo Alarm	Hi & Lo Alarm	
GULTON PART NUMBER	M-20453	M-23055	M-23056	M-24052	M-20253	M-23057	M-23058	

The Console Deep Body Temperature Module shall permit setting High and Low Temperature Limits and continuously display the measured temperature from the probe. No adjustments shall be required to maintain calibration and interchangeability of transducers.

Transducers shall be M-20040 Gulton or equivalent, Display and Alarm Module shall be M-230S5 Gulton or equivalent.

3.2.1.3 Skin Temperature - A small flat thermistor probe shall be attached to the lower sternum and detect changes in skin temperature. This measurement shall be made, displayed and alarmed identical to that described in paragraph 3.2.1.2.

Transducers shall be M-20060 Gulton or equal, Display and Alarm Module shall be M-230S6 Gulton or equal.

3.2.1.4 Respiration Rate - A small light-weight nostril thermistor assembly shall be clipped to one nostril of the subject. The transducer shall be connected to the Junction Box which shall amplify the respiratory characteristics to levels and with suitable impedances for hard wire transmission as described in paragraph 3.2.1.1. The Console Respiration Rate Module shall permit setting High and Low Rate Limits, indicate averaged breathing rate on a meter face and provide an output for recording.

A visual indication of each respiratory cycle shall also be indicated. No front panel adjustment shall be required.

Transducer shall be M-32CB2A Gulton or equivalent, Junction Box Signal Conditioner shall be M-284 Gulton Respiration, or equivalent. Display and Alarm Module shall be Gulton M-240S2 or equivalent.

3.2.1.5 Suit Pressure - A light-weight, 1/8" diameter, flexible tube shall be connected from the helmet to the Junction Box where a light-weight, frictionless differential transformer pressure transducer and accompanying electronics shall be housed. An electrical output from the Junction Box shall be proportional to the applied pressure in the helmet. The console Pressure Module shall permit setting High and Low Pressure Limits, continuously indicate helmet pressure and provide an output for recording. Zero and Full Scale panel adjustments shall be provided.

Transducer shall be P-100G Gulton or equivalent, Junction Box Signal Conditioner shall be M-284BP Gulton or equivalent, Display and Alarm Module shall be M-202S3 Gulton or equivalent.

3.2.1.6 Suit Temperature (Inlet) - A thermistor probe assembly shall be attached to the air inlet line of the pressure suit and sense outlet air temperature. The probe shall be protected from damage by means of a suitable housing over the thermistor element. Temperature measurements shall be made, display, and alarmed, identical to that described in paragraph 3.2.1.2.

Transducer shall be M-20090 Gulton or equivalent, Display and Alarm Module shall be M-230S7 Gulton or equivalent.

3.2.1.7 Suit Temperature (Outlet) - The measurement shall be made identical to that described in paragraph 3.2.1.6.

Transducer shall be M-20090 Gulton or equivalent, Display and Alarm Module shall be M-230S8 Gulton or equivalent.

3.2.1.8 Provision for Spare Channels - Junction Box and Monitoring Console shall be provided with sufficient capacity for adding up to five additional physiological channels.

3.3 Component Description and Requirements

3.3.1 Junction Box - Shall be Gulton M-765 or equal. Connectors shall be subminiature, coaxial, low-noise type, Gulton C5P and C5R1 or equivalent. Connector to umbilical shall be Cannon MD1-25SL1 or equivalent.

3.3.1.1 Power Supply Voltage - The Console Power Supply Module, Gulton M-299S1, or equivalent, shall supply regulated 12 VDC with suitable capacity and regulation to energize the various physiological signal conditioners in the Junction Box utilizing the umbilical specified in paragraph 3.2.1.1.

3.3.2 Display and Alarm Modules - All display and alarm modules shall contain their own built-in power supply which operates on 110-120 volts 60 cycle power. Each Module shall be capable of being removed from the Monitoring Console and connected directly to the Junction Box for remote and in-process checkout. Each module shall be fully transistorized. Each alarm function shall be derived from a self contained 3½ inch scale solid state control meter which is mounted on the front panel of the module. The meter shall be of a contactless read-through type. High and Low set point adjustments shall be provided by control knobs on the front panel. Pointers shall be adjustable over the full scale of the meter or down to one angular degree between set points. Deadband at make-point to be $\pm$ ¼% full scale. Switching point to be 1% of set point. Switch action at set points to be instantaneous and repeatable. Each switching function shall be accompanied by a slave relay rated at 110 volts, 5 amperes.

3.3.3 Transducers and Attachment - Each transducer shall be attached to the subject in the manner and at the location indicated in G.E. Dwg. 201R806. Two complete sets of spare interchangeable transducers shall be provided with the system.

3.3.4 Monitoring Console Configuration - The Monitoring Console shall contain the following Display and Alarm Modules which are plugged-into a 16 module capacity housing. Each module shall be provided with a quarter-turn Dzus fastener which will lock it in place in the Monitoring Console.

Physiological Module	Quantity
Electrocardiograph	1
Heart Rate	1
Deep Body Temperature	1
Skin Temperature	1
Respiration Rate	1
Suit Pressure	1
Suit Temperature (Inlet)	1
Suit Temperature (Outlet)	1
Power Supply	1

The Monitoring Console shall be made up of a number of housings, each with a four module capacity. Each housing shall be of standard 19 inch rack size and 8-3/4 inches high. Depth behind the panel shall be 15 inches maximum. The configuration of the Monitoring Console shall be in accordance with General Electric Company Drawings 201R803, and 253E553.

3.3.5 Cabling and Connectors - All cabling from transducers to junction box shall be supplied by the vendor in accordance with G. E. Drawing 201R806.

3.4 System Calibration - Prior to each use of the Bioinstrumentation system a system calibration shall be made of the system from the junction box to the readout. This calibration shall be made with a system calibrator.

3.4.1 System Calibrator - A portable battery operated system calibrator shall be supplied which is capable of providing calibrated input signals for the physiological parameter shown below. The calibrator shall be capable of being connected to the Junction Box and supply the following signals:

Simulated Signal	
ECG	Normal clinical quality electrocardiogram with P,Q,R,S,T, & U waves at rate of 80 ± beat/minute
Body Temperature	approximately 98°F , ±.1°F
Skin Temperature	approximately 90°F , ±.1°F
Respiration Rate	square wave respiratory cycle, inhale, hold, exhale at rate of 15 breaths per minute, ± cycle/minute
Suit Temperature (Inlet)	Approximately 65°F , ±.1°F
Suit Temperature (Outlet)	Approximately 95°F , ±.1°F
Suit Pressure	Adjustable range of 0-25 psia capability ± 0.5 psia

APPENDIX E

DESIGN CONSIDERATIONS

CONTROL CONSOLE SYSTEM

INTRODUCTION

The function of the Control Console System is to provide comprehensive and continuous monitoring and control of all parameters necessary to insure the well being of suited test subjects and unsuited rescue personnel in a space simulated environment with a minimum of personnel. In order to accomplish the above three major factors had to be considered; the configuration and location of the various consoles, selection of the parameters to be monitored and their function and component design and for selection to effect display and control of the significant parameters.

SYSTEMS DESIGN

CONSOLE CONFIGURATION

The location of the Control Console System will be on a second floor as presently planned, immediately above the manlock, as shown on a sketch supplied by NASA-LRC (to G. E. Company). This area is designated as the "Control Room".

The configuration and location of the various control consoles, is of a circular nature as determined by G.E./NASA technical meetings. Three of the allocated locations are bays which are actually cut into the cylinder itself. Commencing with the first cylinder cutout (lower left in sketch plan view) and proceeding in a clockwise direction the console orientation is as follows:

1) Test Conductor Console

2) Biomedical Console - Test Subject #2

3) Biomedical Console - Test Subject #1

4) Biomedical Console - Rescue Personnel

5) Systems Control Console

6) Test Equipment

7) Research Project Engineer Station

The last two, items (6 and 7) are not considered further here since they are dictated by the requirements for a specific test.

A communications system to link control console personnel to suited test personnel and rescue personnel will be evolved at a later date. To accommodate this future design space has been allocated at the test conductor console, biomedical consoles, and rescue personnel console to house or mount selected equipment.

A visual link via actual viewing ports in chamber walls closed-circuit TV cameras and monitors will be finalized at the time of the chamber modification program. A tentative layout of such is shown on the aforementioned sketch of control room area.

PARAMETER SELECTION AND FUNCTION

The parameter selection and function can best be described by verbally depicting each console separately.

(a) Test Conductor Console - Drawing No. 253E554

The test conductor will man this console. The primary function of this console is to make the test conductor cognizant of the environment of the main chamber, both manlocks and the status of the various subsystems throughout the vacuum chamber facility. In addition to this

he will have exclusive access to the emergency repressurization controls for the manlocks and chamber.

The pressure and temperature of each manlock and the chamber are displayed and recorded to show environmental conditions.

The status section of the console panel consists of a series indicating lights on a graphic panel depicting the on-off condition of the main chamber pumping system. The status of various ECS & RECS components is also shown via indicating lights.

An area on the test conductor panel will be provided for emergency repressurization controls. Emergency repressurization switches will be needed to effect rapid repressurization of both manlocks separately and the chamber and manlocks simultaneously. As agreed, NASA will be responsible for the design and implementation of necessary controls. Scheme for effecting this control sequence is depicted in Appendix L, Figure 2-L.

With the exception of the emergency repressurization controls the test conductor is strictly an overseer with decision making authority and is free to move about the control room area.

(b) Test Subject Biomedical Console Drawing No. 253E553

The biomedical console is identical for each subject. These consoles will be monitored by a medical technician-type who will be exclusively a monitor. In light of this, control features have not been incorporated into the biomedical console. Any controllable parameters displayed at the biomedical console will be controlled at the "Systems Control Console" to be discussed later.

The basic biomedical parameter to be monitored are functionally described in the "Biomedical Instrumentation" section of this report. The suit parameters, pressure and temperature, are considered to be a part of biomedical instrumentation and described as such in the referenced section. A six channel recorder will be provided to continuously record the six biomedical parameters.

In addition to the above parameters there are ECS parameters which must be considered as critical in the determination of a suited test subject's well being. The ECS parameters, which are recommended to be monitored in Reference 1, are oxygen and carbon dioxide partial pressure, total pressure at ECS outlet, ventilating flow rate, and ECS outlet temperature. Coolant inlet and outlet temperature displays are provided for use with liquid cooled suits.

(c) Biomedical Console-Rescue Personnel Drawing No. 201R803

The rescue personnel biomedical console contains biomedical data for both of the rescue personnel. The display of rescue personnel biomedical data is justified because of the potentially hazardous environment in which the unsuited personnel are subjected. The data will be monitored by a medical technician type and, as on the test subject biomedical console, he will not have any control responsibility. The controls are displayed on the "Systems Control Console".

The biomedical parameters discussed in the "Biomedical Instrumentation" section of this report are displayed for each of the rescue personnel, with the exception of the suit parameters since suits will not be worn. A recorder is provided to continuously record the four biomedical parameters.

The same critical parameters listed for the test subject environmental control systems are displayed for the rescue manlock environmental control system.

In addition to the above displayed parameters the temperature and pressure in the rescue manlock are displayed, such that bio-medical monitor can be aware of the overall environment surrounding the unsuited rescue personnel.

(d) Systems Control Console - Drawing No. 201R804, Figures 4, 5, 6

The systems control console is the center for controlling the required parameters of the test subject ECS's and the RECS. In addition to control meters it houses meters indicating the status of various ECS and RECS components and parameters. The chamber and manlock parameters are displayed also. Controls governing normal repressurization and depressurization of both the rescue and test manlock are provided. A hardware technician type will monitor and effect the control of the displayed parameters per the instructions of the test conductor.

The following description is virtually the same for the three environmental control systems (i.e. suits 1 & 2, RECS). Any differences will be so noted. The control meters selected have the similar characteristics of being equipped with adjustable "high" and "low" control settings and warning limits. The control meters have a light to indicate that high or low limits are exceeded. In most cases the set limits will merely serve as a warning device. The control meter circuit to power lights, relays, etc., unless noted, is "open" between limits and "closed" when limits are exceeded.

Each light whether with a meter or merely indicating that a unit is "on", etc. will be equipped with a "test" button to verify that the bulb is functional.

Air flow rate and total pressure at the ECS outlet are displayed via control meters. The flow rate is measured by the use of a 0 to 1 PSID differential pressure transducer across a venturi flow meter. The total pressure is measured by an absolute pressure transducer over the range of 0 to 20 PSIA. Flow rate is dependent on both Δ P and total pressure. The ΔP across the venturi ranges from approximately 3" H_2O to 20" H_2O and the total pressure can vary from 4.5 to 18.2 PSIA. Therefore a different flow rate will result at the same ΔP for different total pressures. Since the flow display meter is dependent on the ΔP transducer output a flow correct device must be employed to compensate for different total pressures. This is accomplished by use of a logarithmic variable resistor to control the current output of the ΔP transducer through the control meter. In order to determine the correct flow rate the variable resistor dial must be set to the total pressure indicated, thus selecting the resistance value which will allow the correct current to flow through the meter. The meter will indicate flow in cubic feet per minute. A bidirectional momentary switch is provided in order that the systems monitor may increase or decrease flow.

The test subject ECS requires utilization of the low control limit of the outlet pressure meter to activate emergency repressurization solenoid valve (SV-1) via a relay as shown on Figure 4E.

The partial pressure of oxygen and carbon dioxide is controlled by control meter limits. In addition to providing visible warning the p O_2 control meter limits are used to control the desired pO_2 level via low flow oxygen make-up solenoid valve (SV-2) as shown on Figure 4-E. The required oxygen control sequence demands a non-standard output from the control meter circuitry.

The utilization of signal output converter (item 31) provides the following control sequence. The "high" limit contact is closed for all pO_2 below high limit setting and the "low" limit contact is closed only below low limit setting. Therefore, when pO_2 is below low limit the make-up solenoid valve opens increasing pO_2. Because of the non-standard sequence, i.e., "high" limit contact closed, oxygen will be supplied until the pO_2 high limit is reached.

The ECS outlet temperature is sensed by use of a temperature transducer with an output compatible to the control meter and a recording device. The heat exchanger outlet temperature is sensed by a thermistor. The bridge circuitry necessary for temperature indication with thermistors is at the control meter. All ECS & RECS temperatures have a full scale meter range from 30° to 120°F. The ECS outlet temperature is controlled by use of a control meter and a potentiometer (variac) which controls the power input to the heater in the ECS. The heat exchanger outlet temperature is monitored via an indicating meter. Knowledge of these temperatures will indicate the relative humidity of the ventilating air to the suit if saturated air is assumed at the heat exchanger outlet. The R.H. can then be determined by use of a psychrometric chart, or by using the ratio of the saturated vapor pp at the Hx outlet temperature to that atthe exit of the reheater.

When liquid cooled suits are used the inlet and outlet temperature of the coolant to the suits are displayed. Both temperatures are sensed by thermistors however, the inlet temperature is displayed via a control meter and the outlet temperature by an indicating meter. The inlet temperature desired can be set by a dial on the panel which regulates the temperature controller in the ECS. The coolant pump current is also displayed to indicate the pump operational status. A switch to activate suit coolant pump is also provided.

The operational status of the blower and heat exchanger coolant pump are displayed by ammeters. A control meter is used for blower suction pressure. An absolute pressure transducer is used for pressure sensing. The high limit contact is used to control the ECS vacuum pump solenoid valve (SV-5) during pump down of the ECS and suit as shown on Figure 4-E. This additional control feature is not necessary in the RECS so the limits on the meter serve as a warning only. The coolant tank temperature is shown by an indicating meter via a thermistor. The tank pressure of the ECS & RECS gases are displayed by use of gage pressure transducers and indicating meters.

Switches to initiate system components (pumps, blower, etc.) ESC purge and in the case of the test subjects, suit purge are provided on systems control panel. Indicating lights signifying unit "on" status are provided as required.

The environmental control system outlet pressure and temperature and oxygen and oxygen and CO_2 partial pressures are recorded continuously at the console to provide a quick reference to monitor and a permanent record of data for post test examination.

The systems monitor will be aware of the chamber and manlock environments as well as having normal pressure control of both the rescue and test manlocks. Temperature and pressure of these three areas are displayed. Absolute pressure and temperature transducers are used respectively for the ranges of 0 to 800 mm Hg and 0^{o} to 200^{o}F.

In order that the approach to pressure equalization between the manlocks and chamber and manlocks and ambient during pump "down" or pump "up" might be sensed, differential pressure transducers are used. Adequate pressure overload protection is provided inherent to the transducer. The range of transducers are 0 to 0.2PSID. Indicating meters are used to display differential pressures.

The rescue manlock control consists of a switch on the panel for depressurization or repressurization. In conjunction with the depressurization phase the limit settings of the rescue manlock total pressure control meter are used to open and close the solenoid between the vacuum pump and manlock. A rate of climb meter measuring pressure rate of change during normal depressurization phases is also provided. Overload protect for this meter is provided via a relief valve, for emergency conditions.

The test manlock controls are shown with a graphic panel depicting existing facilities at Langley Research Center as shown on LRC drawing no. 702914. A rate of climb meter, as described above, is included with the controls.

COMPONENT DESIGN AND ANALYSIS

To discuss components utilized in the Control Console System it is convenient to delineate by function because of the redundant instrumentation. The following represents the description and analysis of each component and the locations of their usage.

Biomedical Read-outs and Recorders

(a) All biomedical read-out instruments are manufactured by Gulton Industries, Inc. and are discussed along with the biomedical sensors under a separate section, "Biomedical Instrumentation", Appendix D, of this report. The recorders utilized are also manufactured by Gulton Industries. A single channel recorder, model #M215, will be used to record ECG data. It has an input range of ± 100 mv DC - 100 cps. The recorder is equipped with a six-speed paper drive. A six-channel recorder, model # M-260, is used to record data from the remaining biomedical paramters. The input required is merely the output of the biomedical modules.

The above readouts are used for the test subject biomedical console (drawing 253E553 and the rescue personnel biomedical console (drawing #201R803).

(b) Absolute Pressure

1. Usage and Readout Location	Drawing Number
a) ECS outlet pressure	253E553, 201R804
b) RECS outlet pressure	201R803, 201R804
c) ECS blower inlet pressure	201R804
d) RECS blower inlet pressure	201R804

Transducer

The transducer selected is manufactured by Consolidated Controls Corp., Bethel, Conn. and it is a type 41GP1. The transducer range is 0 to 20 PSIA, input is 115V, 60 CPS and the output is 0-5 VDC. Electrical connections are made, via a removalbe cover and port, to a terminal strip. It has an all-welded sensor thus eliminating problems with seals, etc. and can be easily adapted to the ECS. Consolidated Controls Corp. submitted the only bid for this instrument.

Meters

A control meter with adjustable high and low settings manufactured by International Instruments Inc., Orange, Conn. is used. The model no. is 2548-24L with 28 VDC input for control circuitry. The input required for readout is 0-5 VDC and scale range is 0 to 20 PSIA, ± 2%. It is an edge-wise meter reading horizontal. The flexibility of this type meter, i.e., compatibility to almost any input, adjustable high - low limit settings and compactness (1.4" x 4.4") warrants its usage for display.

2. Usage and Location	Drawing Number
a) 55' chamber pressure	201R804, 253E554
b) Test manlock pressure	201R804, 253E554
c) Rescue manlock pressure	201R804, 252E554, 201R803

Transducer

Consolidated Controls Corp., type 41GP1 with range to 0 to 800 mm Hg., input 115 V, 60 CPS, and output of 0 to 5 V.

Meter

a) For the rescue manlock pressure a control meter is needed, therefore, International Instrument Inc. model no. 2548-2HL with 0 to 5 VDC input and scale range 0 to 800 mm Hg., ± 2%, will be used. 28 VDC is needed for control input.

b) For the test manlock and chamber an indicating meter only is required. International Instrument Inc. model no. 2500-HL with 0-5 VDC input and scale range 0 to 800 mm Hg., ± 2%. This meter is identical in size and appearance to the control meter thus affording uniformity to control console panels.

(c) Gage Pressure

1. Usage and Location

	Drawing Number
a) ECS tank pressures (O_2, N_2, emergency O_2)	201R804
b) RECS tank pressures (O_2, N_2)	201R804

Transducer

Consolidated Controls Corp. type 41GP1 with range 0 to 2000 PSIG, input 115 V, and output of 0-5 VDC.

Meter

International Instrument model no. 2500-HL with input of 0 - 2000 PSIG, $\pm$ 2%.

(d) Differential Pressure

1. Usage and Location

	Drawing Number
a) Rescue manlock to chamber	201R804
b) Rescue manlock to ambient	201R804
c) Test manlock to chamber	201R804
d) Test manlock to ambient	201R804

Transducer

Consolidated Controls Corp. has been selected to provide the transducer for measuring the differential pressure range necessary for cognizance of manlocks to chamber and manlocks to ambient pressure equalization. The unit, part no. 41PA1-6, can be used for all cases mentioned above. It's range is 0 to 0.2 PSID F.S. $\pm$ 1% with input of 28 VDC and output of 0-5 VDC. This unit provides the necessary overpressure protection required by the extreme pressure differences encountered in a system of this nature. Consolidated Controls Corp. has experienced satisfactory results in a unit of this type supplied to the Naval Ordnance Labs at Silver Springs, Md. for a similar application.

Meter

International Instruments model no. 2500-HL with input of 0 to 5 VDC and scale range of 0 to 0.2 PSID, ± 2%.

(e) Temperature

1. Usage and Location	Drawing Number
a) Chamber temperature	253E554
b) Rescue manlock temperature	253E554, 201R804
c) Test manlock temperature	253E554, 201R804

Transducer

Consolidated Controls Corp. temperature transducer part number R427L20 with range of 0 to 200°F, input of 28 VDC, and output of 0-5 VDC will be used. The advantage of this unit over thermistor sensing is that no additional circuitry is needed between sensor and readout. This unit simultaneously provides an output to the meter and to a recorder.

Meter

International Instruments model no. 2500-HL with input of 0 to 5 VDC and scale range of 0 to 200°F, ± 2%.

2. Usage and Location	Drawing Number
a) Chamber temperature	201R804

Transducer - Meter

A multi-point temperature indicator, item 32, with thermocouple probes is used to monitor temperature at various points in the 55' vacuum chamber. The manufacturer is Consolidated Controls Corp., Temptron Division, Reseda, California. The unit, part number 2650-12-J2, has a range of 0-300°F and is a standard, off-the-shelf item. The part number calls out the thermocouple, but probes should

be specified (size, fitting, etc.) according to NASA/LRC. The unit lends itself readily to panel mounting.

3. Usage and Location	Drawing Number
a) ECS outlet temperature	253E553, 201R804
b) RECS outlet temperature	201R803, 201R804

Transducer

Because of the desired recording capabilities Consolidated Controls Corp. temperature transducer, part no. 427L029 will be used. The unit has a range of 30° to 120°F with input of 28 VDC and output of 0 to 5 VDC, ± 2%.

Meter

International Instruments Control meter model no. 2548-246 with 28 VDC input for control electronics and 5 VDC input for meter with scale range of 30° to 120°F, ± 2%.

4. Usage and Location	Drawing Number
a) ECS heat exchanger outlet temperature	201R804
b) RECS heat exchanger outlet temperature	201R804
c) Suit coolant inlet temperature	201R804, 253E553
d) Suit coolant outlet temperature	201R804, 253E553
e) ECS coolant tank temperature	201R804
f) RECS coolant tank temperature	201R804

Transducer - Meter

With the exception of the suit coolant inlet temperature, which requires a control meter, all of the above use indicating meters. International Instruments can provide their standard indicating meter with an adapter containing thermistor sensing network to operate off a 20000HM type thermistor. The model no. of the meter is 2500 HL, 050 DCUA (S) and has a range of 30° to 120°F, ± 2%. The thermistor is similar to Fenwal Inc., Ashland, Mass. cat. no. 74502-106.

(f) Rate of Pressure Change

1. Usage and Location

	Drawing Number
a) Rescue manlock rate of climb	201R804
b) Test manlock rate of climb	201R804

Meter

The meter, which is directly connected to the manlocks, is manufactured by Kollsman Instrument Co., Elmhurst, New York part no. D071631D005 which meets the requirements of AN 5825. It has a range of 0 - 6000 ft/min. (approximately 1 PSI/min.) for increasing or decreasing pressures. A relief valve is provided for overload protection during emergency repressurization.

(g) Partial Pressure

1. Usage and Location

	Drawing Number
a) ECS oxygen partial pressure	201R804, 253E553
b) RECS oxygen partial pressure	201R804, 201R803
c) ECS carbon dioxide partial pressure	201R804, 253E553
d) RECS carbon dioxide partial pressure	201R804, 201R803

Transducer (Analyzer)

For carbon dioxide an M.S.A. model M300 analyzer with 0 to 100 mv output is used. For oxygen a Beckman analyzer with 0 to 100 mv output is used. Reliability of these instruments, demonstrated by G. E. Life Support Engineering laboratory usage, dictated their selection.

Meter

a) Carbon Dioxide - International Instrument model 2548-246 control meter with scale range of 0-20 mm Hg. and input of 0 - 100 mv for meter.

b) Oxygen - Because of the unique control requirements, delineated in a preceding section, the International Instrument model no. 2548-2[illegible] requires an output signal converter. This unit equipped with meter-compatible octal socket is also manufactured by International Instrument and is specified by MARK 4049 Adap-Trol. The control meter has a dual scale (0 to 1200 mm Hg. and 0 - 300 mm Hg.) with adjustable limits on low scale. It has an input of 0 to 100 mv for meter. Redundant lights are provided to signify that the emergency oxygen valve has energized.

(h) Flow

1. Usage and Location	Drawing Number
a) ECS outlet	201R804, 253E553
b) RECS outlet	201R804, 201R803

Transducer - Meter

Because of the simultaneously varying parameters, ΔP across venturi and ECS outlet pressure (P), the flow is not linear with respect to ΔP. This necessitates the implementation of a flow correction device, as delineated in a preceding selection, between the differential pressure transducer and flow readout meter. An analysis and solution follows:

The equation for computing flow through a venturi is, from ref. 7:

$$W = \frac{C}{\sqrt{1-B^4}} \left[\left(\frac{K}{K-1} \right) \frac{(1-B^4)\ (1-r^{k-1/k})}{(1-B^4 r^{2/k})\ (1-r)}\ r^{2/k} \right] A_2 \sqrt{2g\rho_1\ (P_1-P_2)}$$

where: W = mass flow is lbs/min.

$$\frac{C}{\sqrt{1-B^4}} = \text{flow coefficient (K) - dimensionless}$$

$$\left| \frac{K}{K-1} \quad \frac{(1-B^4)}{(1-B^4 r^{2/k})} \quad \frac{(1-r^{k-1/k})}{(1-r)} \quad r^{2/k} \right| = \text{adiabatic expansion term } (Y_1) \text{ - dimensionless}$$

A_2 = area orifice in in^2

ρ_1 = density lb/in^3 (upstream)

$P_1 - P_2 = \Delta P$ = pressure difference across venturi in PSI

Equation reduces to:

$$W = KY_1A_2 \sqrt{2g\rho_1 (\Delta P)}$$

For a well designed venturi $K = Y_1 = 1$ (ref. 7)

Assuming this and knowing $W = CFM (\rho)$

From the above relationships, it can be seen that:

$$CFM \sim \sqrt{\frac{\Delta P}{\rho}} \quad \text{and } \rho \sim P$$

$$CFM \sim \sqrt{\frac{\Delta P}{P}}$$

We now have an expression in terms of the three measurable parameters flow, differential pressure, ΔP, and total pressure (P). The possible ranges of P and ΔP are:

$4.5 \leq P \leq 18.2$ (PSIA)

$3.21 \leq P \leq 20.0$ (In. H_2O)

For the particular venturi in the ECS at P = 4.5 PSIA,

and flow = 6.0 CFM ΔP = 3.21" H_2O

when flow = 15.0 CFM ΔP = 20.0" H_2O

i.e., assuming a constant ΔP = 20" H_2O and varying P

$$\frac{CFM_1}{CFM_2} = \sqrt{\frac{\Delta P/P_1}{\Delta P/P_2}} = \sqrt{\frac{P_2}{P_1}}$$

$$CFM_2 = CFM_1 \sqrt{\frac{P_1}{P_2}} \qquad \text{(Eq. 1)}$$

@ ΔP = 20" H_2O ; P_1 = 4.5 PSIA and CFM_1 = 15.0

As P_2 varies from 4.5 to 18.2 PSIA for suit pressures 3.5 to 17.2 PSI calculations using Eq. 1 above show that for a ΔP of 20" H_2O the following values apply:

P	CFM
4.5	15.0
6.0	13.0
8.0	11.2
10.0	10.0
14.0	8.5
16.0	7.95
18.2	7.50

TABLE 1

The ratio of flows exhibited above (e.g. $\frac{4.5}{6.0}$ as $\frac{15.0}{13.0}$) at P = 20" H_2O is true for all ΔP's as shown in equation (1). This results in a family of curves, as follows: The maximum and minimum conditions are shown below:

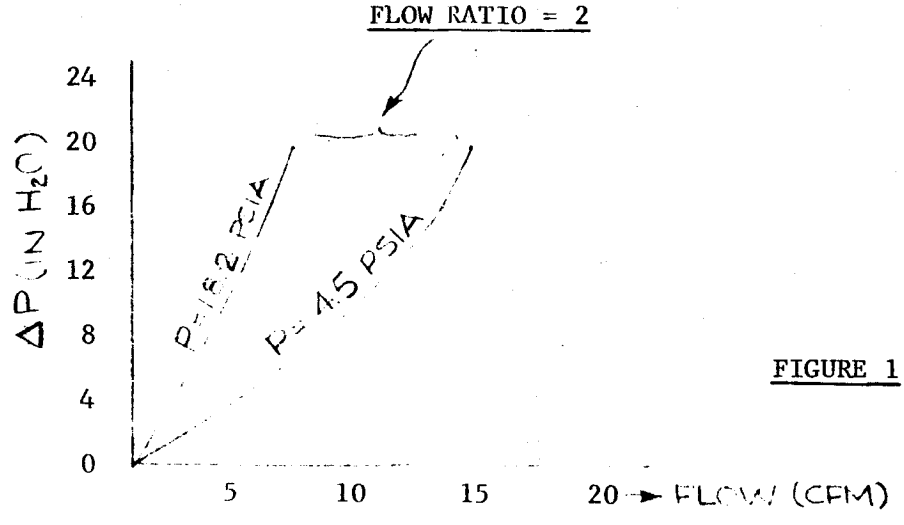


FIGURE 1

Using Consolidated controls ΔP transducer 41GP1-44 with range of 0-1 PSID and output of 0 to 1 ma DC with International Instrument Control meter 2548-2 HL with input of 0 - 1 ma DC and input impedance of 72 ohms the following flow correct circuit can be used.

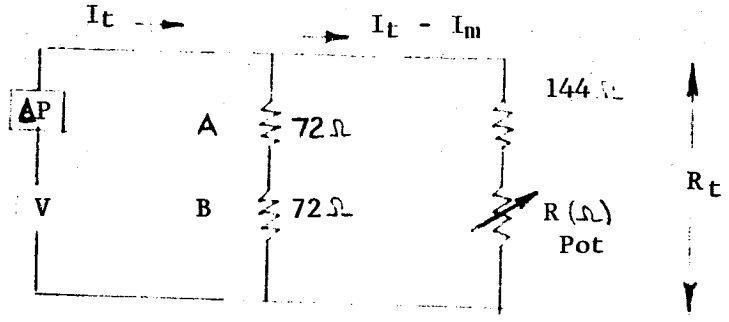


FIGURE 2

where A = meter at Biomed console

B = meter at systems console

when $\Delta P = 20"\ H_2O$

The output of the transducer (Io) will be a

that is, $$\frac{20"\ H_2O}{27.7"\ H_2O/PSI} = \frac{Io}{1\ ma/\ PSI}$$

$$Io = .722\ ma$$

With this 0.722 ma output and P = 4.5 PSIA, CFM = 15. The meter should then read 15 CFM. However, since CFM varies with P at a given ΔP a correction must be effected to modify the meter reading at various total pressures (P).

At 4.5 PSIA, R_{POT} must be very large, say 100 K, to force all transducer output current to flow through meters, that is, 0.722 ma should read 15 CFM. As the pressure increases R_{POT} must vary to allow proper current to flow through meter. The value needed at varying P can be calculated from Figure 2 as follows:

$$R_T = 144 + R_{POT} \quad \ldots\ldots \quad (2)$$

$$R_T = \frac{I_m\ (144)}{I_T - I_m} \quad \ldots \quad (3) \quad I_T = .722 \text{ ma at } 20" H_2O$$

Since each flow meter has an input impedance of 72 Ω and at maximum P the meters should only see ½ of the transducer output current, the selected resistance of 144 Ω is justified since R_{POT} will be zero.

Using equation (3) the following table shows results at $\Delta P = 20" H_2O$

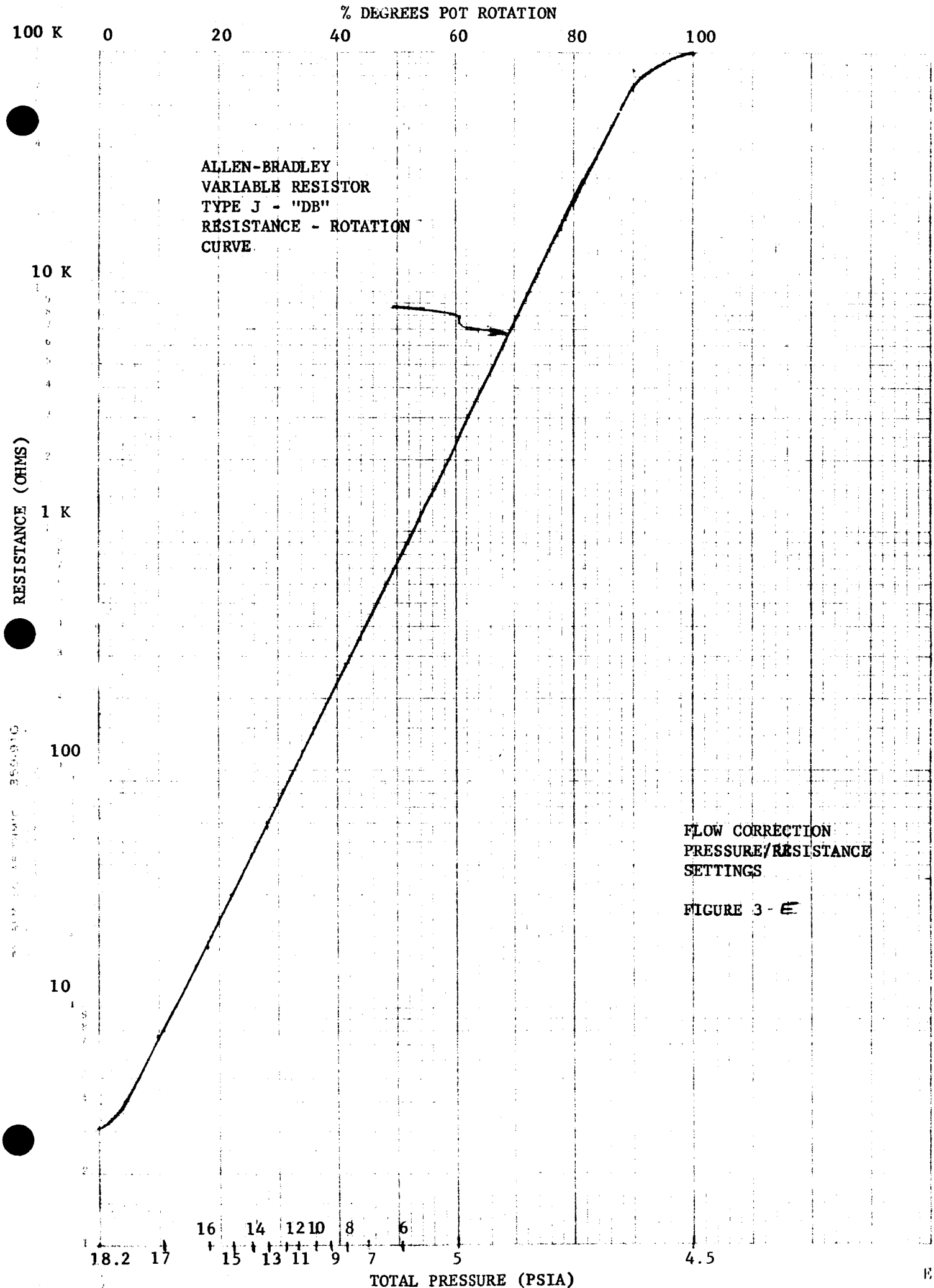
P	CFM	R_T (Ω)	ma (meter)	R_{POT} (ohms)
4.5	15.0	100K + 144 (∞)	.722	100k (∞)
5.0	14.2	2520	.683	2376
6.0	13.0	928	.625	784
7.0	12.0	568	.576	424
8.0	11.2	420	.538	276
9.0	10.6	346	.510	202
10.0	10.00	288	.481	144
11.0	9.55	250	.459	106
12.0	9.19	226	.442	82
13.0	8.80	204	.423	60
14.0	8.50	188	.409	44
15.0	8.22	174	.395	30
16.0	7.95	162	.382	18
17.0	7.70	152	.370	8
18.0	7.50	144	.361	0

TABLE 3

To accomplish the above a logarithmic variable resistor will be used. The resistor to be used is an Allen Bradley type J with "DB" clockwise logarithmic taper giving resistance ranging from 0 to 100 K ohms, over a rotation of 360°. The proper resistance will be set by selecting, via dial, the total pressure (P) at the time a flow reading is desired. The use of this method requires a nonlinear scale on the flow meter as well as on the resistor dial. Drawing 201R804, illustrates the graduations needed on the variable resistor dial, as dictated by Figure 3-E. The readings (Table 3-E) of CFM and current in milliamps must be used to illustrate scale for control meter. Internation Instrument has the flexibility to provide this at a nominal cost.

To summarize operation, it is necessary to note system total pressure (P) and adjust variable resistor R_{POT} to the pressure indicated, before reading the true CFM on the flow meter scale.

The case illustrated is for the ECS air flow and can be duplicated for the RECS flow substituting the higher flow value (140 CFM F.S.) where required.



FLOW CORRECTION
PRESSURE/RESISTANCE
SETTINGS

FIGURE 3 - E

(j) Ammeters

1. Usage and Location — Drawing Number

a) Heat exchanger coolant pump current (ECS & RECS) — 201R804
b) Suit coolant pump current — 201R804

Meter

A General Electric panel meter, type AO-91, with a 3.5 inch meter face has been selected for all A. C. Current Monitoring. Selection was based on its panel adaptability and demonstrated reliability in lab usage. The specific characteristics for above application are catalog number 612X24 with 0 to 3 amp AC ± 2% range.

2. Usage and Location — Drawing Number

a) ECS blower current — 201R804

Meter

General Electric type AO-91, catalog number 612X31, range 0 to 15 amps AC, ± 2%.

3. Usage and Location — Drawing Number

a) ECS blower current — 201R804

Meter

The three phase, 400 cycle blower operators at 200 VAC and 1.5 amp A.C. A G. E. Panel meter of type AO-91 can be used by specifying 400 cycle operation when ordering. Current will be monitored in one branch of the three phase system, thus only one-half of current (.75 amps) will be measured. This will give adequate indication of blower performance. The meter to be used bears catalog number 612X20 with scale range of 0 to 1 amp AC, ± 2%.

(1) Recorders

1. Usage and Location

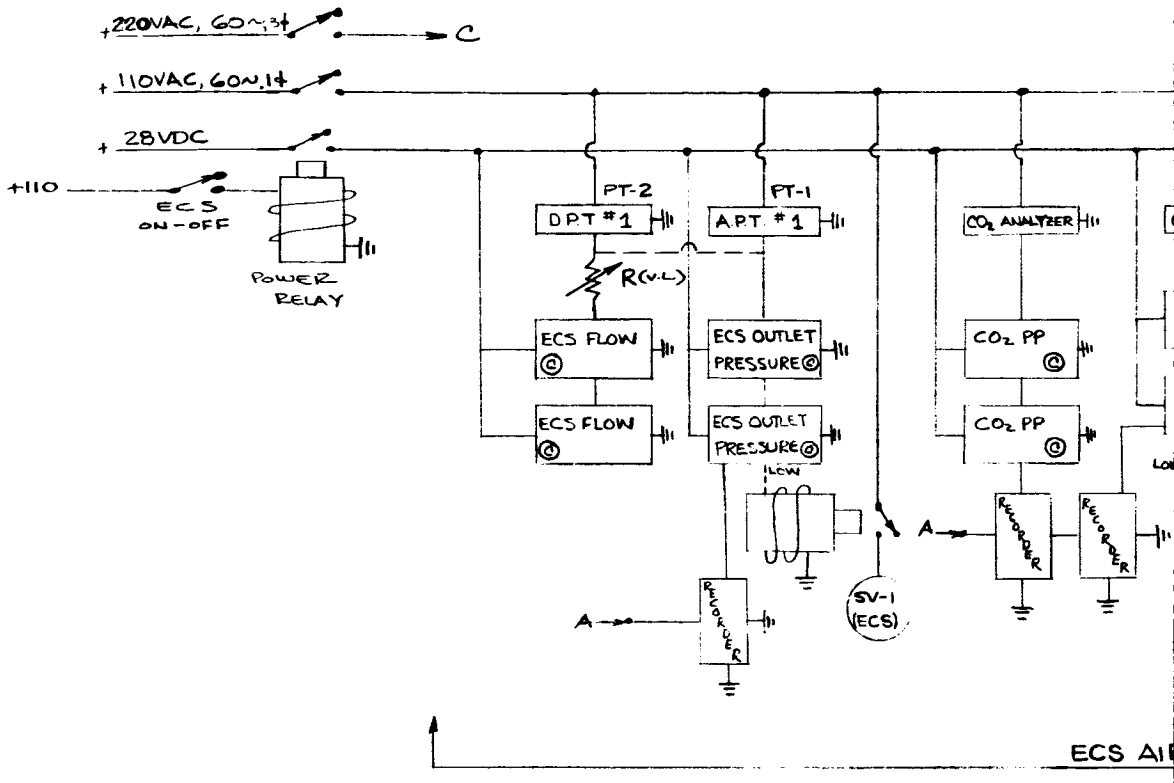
Recorders will be utilized in monitoring parameters which are considered critical and necessary for post test evaluation. They are shown on drawings 201R804 and 253E554, and record the following parameters:

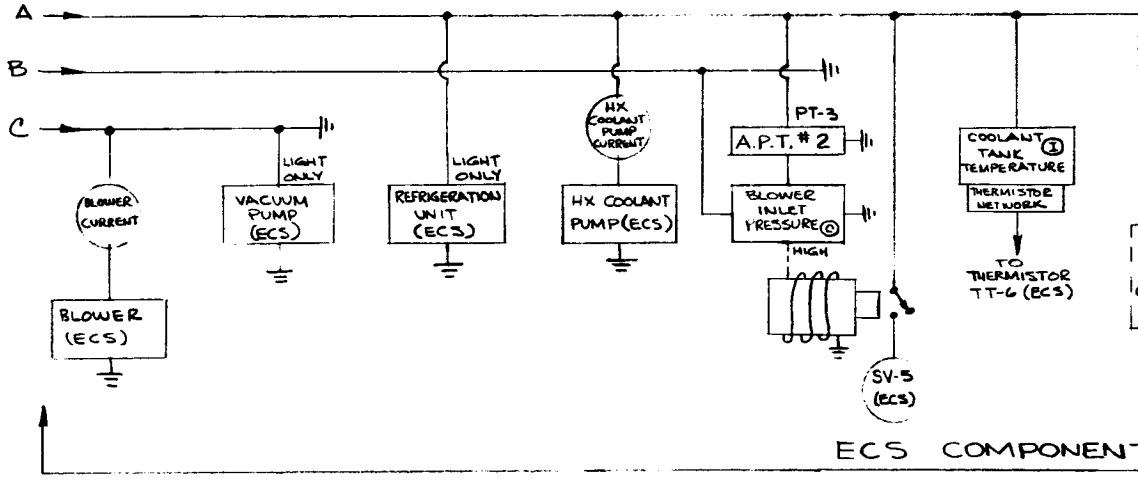
a) Outlet pressure (ECS & RECS)
b) Outlet temperature (ECS & RECS)
c) Oxygen partial pressure (ECS & RECS)
d) Carbon Dioxide partial pressure (ECS & RECS)
e) Pressure (chamber and both manlocks)
f) Temperature (chamber and both manlock)

The recorder selected is compatible with limited space requirements such that two recorders can be located side by side in a standard 19 inch rack. The recorder is manufactured by Esterline Angus, Inc., Indianapolis, Indiana and is entitled Speedservo Recorder, model S601S with power requirements of 120 V, 60 CPS, single phase. They have been quoted to scale required and transducer output for the parameters above. In the case of the chamber parameters a dual speed feature is available in order that the emergency repressurization can be more accurately charted. The switch to high speed can be triggered automatically with the initiation of emergency repressurization.

GENERAL

All connections to be made as shown in schematics, Figures 4-E, 5-E, 6-E. For redundant instrumentation and recording, standard terminal strips should be used for proper routing of transducer output signal. The Systems Control Console can be used as the signal distribution point to facilitate excessive cabling requirements. Relays shown on schematics are International Instrument type A-25391 or equal. Contacts are rated at 5 amp at 120 VAC or 28 VDC.



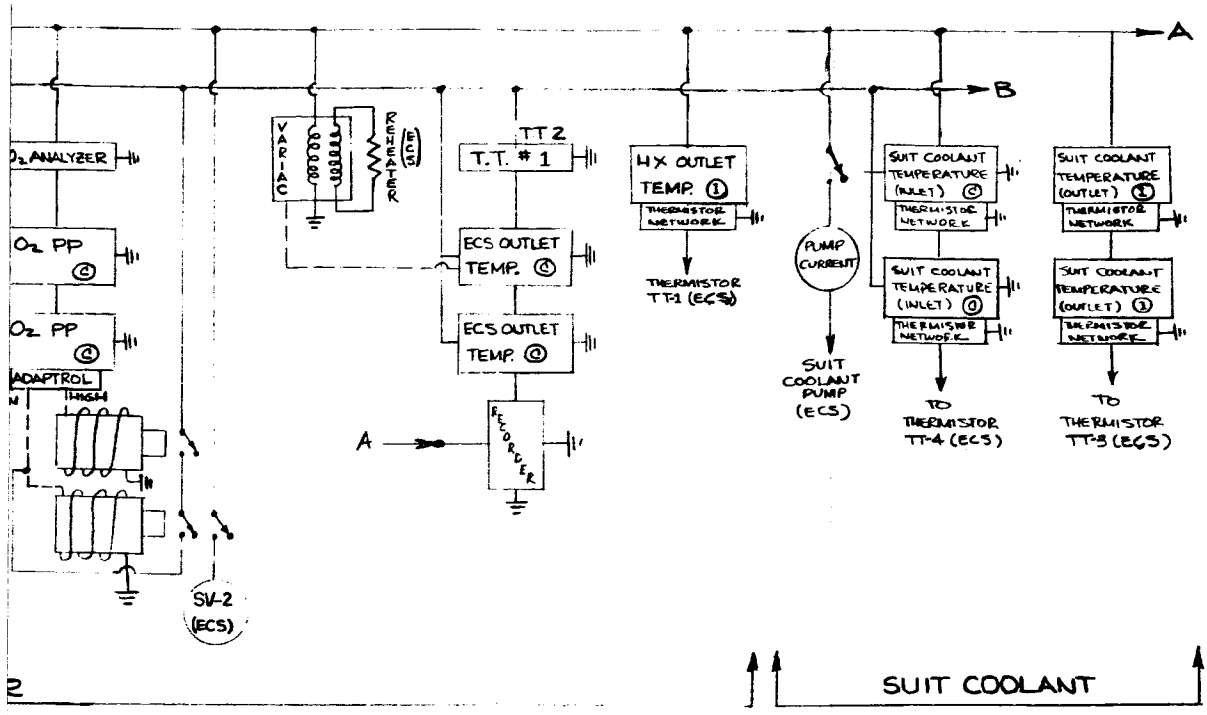


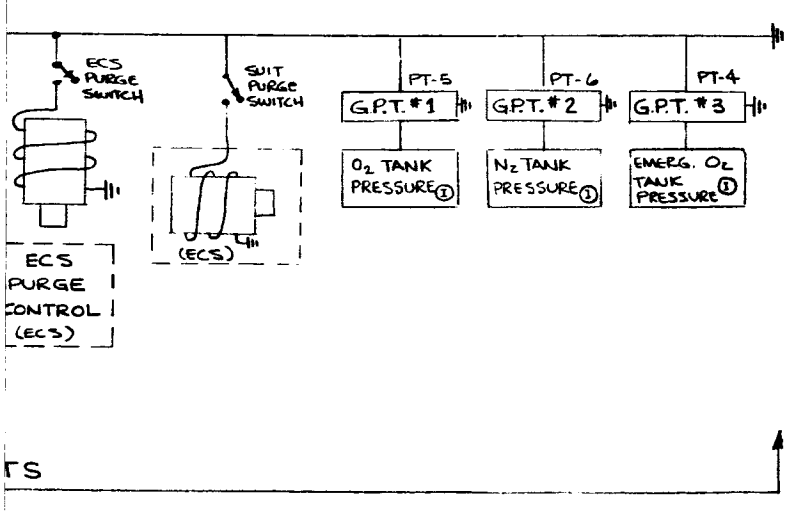
SYMBOLS

1. ▭ – TRANSDUCER
2. ▭ – DISPLAY METER OR UNIT
3. – RELAY
4. ▭ – RECORDER

LEGEND

1. D.P.T. – DIFFERENTIAL PRESSURE TRANSD
2. A P T – ABSOLUTE PRESSURE TRANSDUCER
3. G P T – GAGE PRESSURE TRANSDUCER
4. T.T. – TEMPERATURE TRANSDUCER
5. S.V. – SOLENOID VALVE
6. Ⓒ – CONTROL METER
7. ① – INDICATING METER
8. HX – HEAT EXCHANGER
9. R(V.L.) – VARIABLE LOGARITHMIC RESISTR
10. —— – POWER
11. – – – CONTROL





NOTES

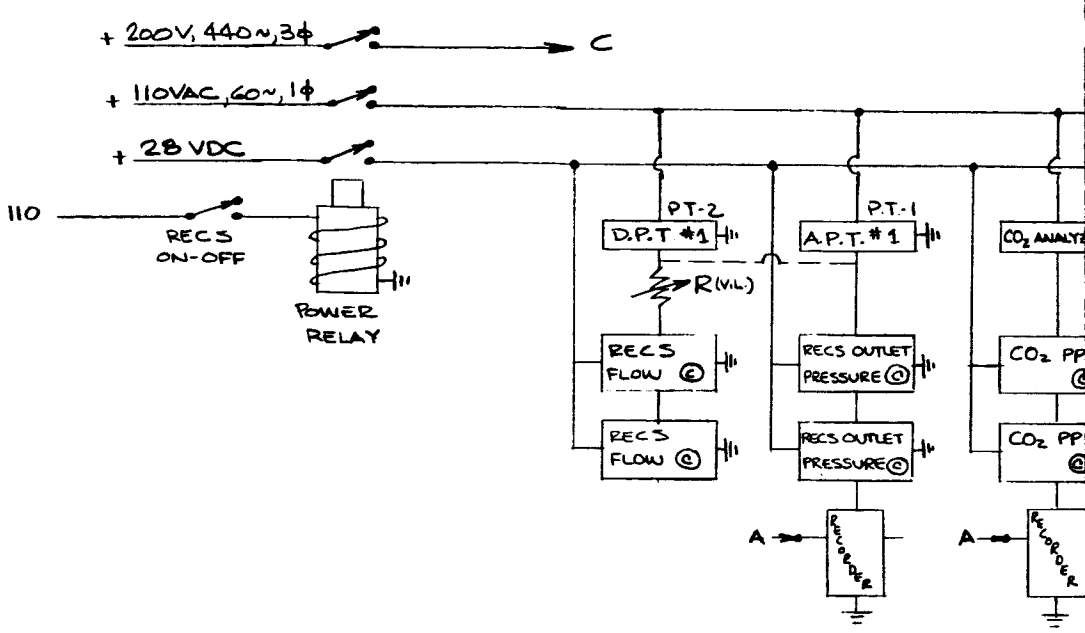
1. (ECS) MEANS UNIT IS LOCATED AT ENVIRONMENTAL CONTROL SYSTEM
2. ALL METERS AND RECORDERS AT CONSOLE
3. WHEN TWO METERS APPEAR IT MEANS PARAMETER IS ALSO MONITORED AT BIOMEDICAL CONSOLE
4. DESIGNATIONS ABOVE TRANSDUCERS REFER TO ECS SCHEMATIC - FIG. 1-A

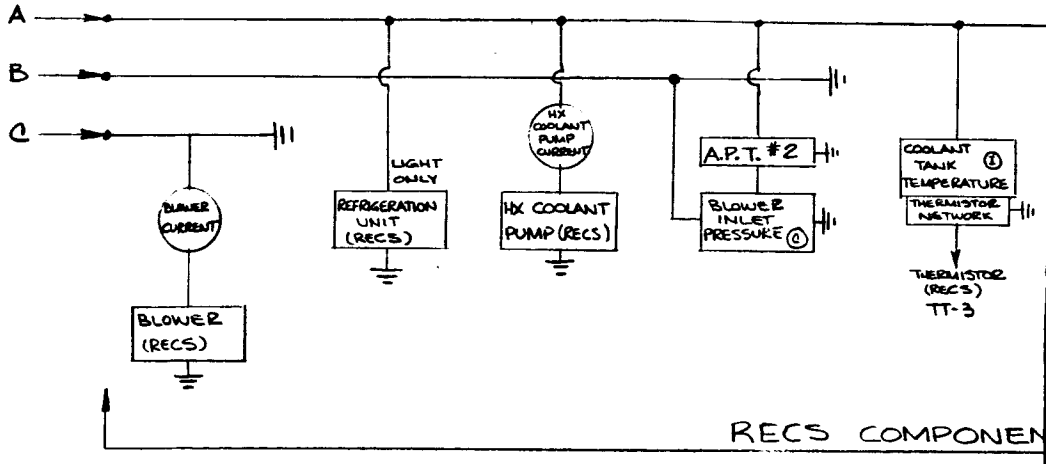
REFERENCES

1. DRAWINGS - 201R804
   - 253E553
2. SCHEMATICS - FIG. 1-A, 2-A (APPENDIX A)

FIGURE 4-E - SCHEMATIC
ECS - TEST SUBJECT

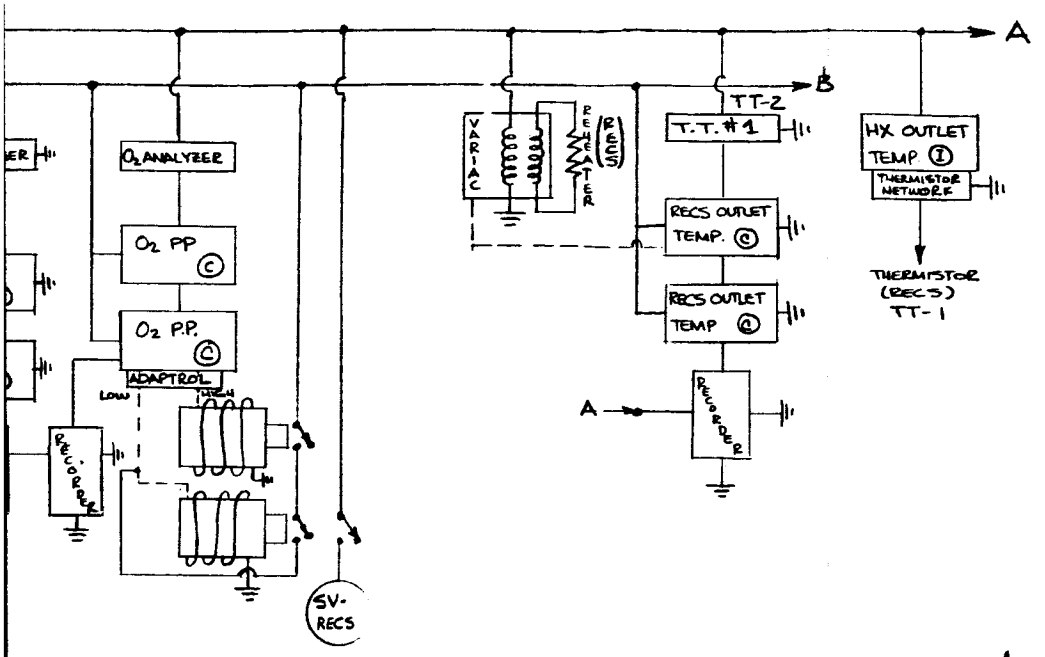
SYSTEM CONTROL CONSOLE

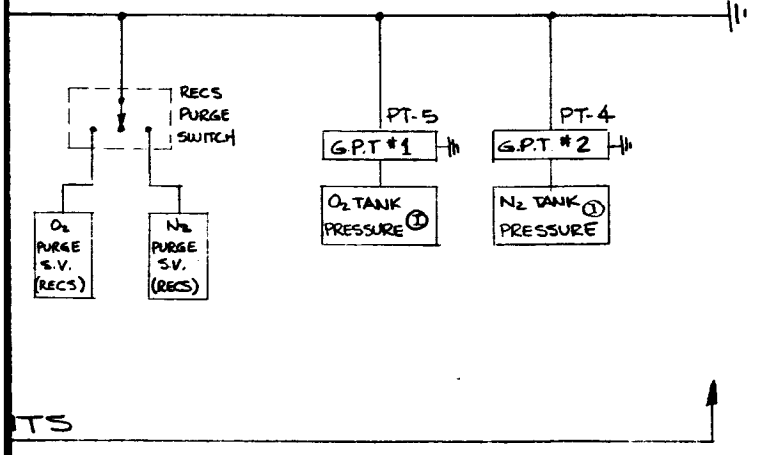




NOTES

1. SYMBOLS AND DESIGNATIONS ARE AS SHOWN ON FIGURE 4-E
2. (RECS) MEANS UNIT IS LOCATED AT RESCUE ENVIRONMENTAL CONTROL SYSTEM
3. SEE NOTE 3 (FIG 4-E)
4. DESIGNATIONS ABOVE TRANSDUCERS REFER TO RECS SCHEMATIC - FIG. 1-B
5. ALL TRANSDU AT RECS
6. ALL METERS A LOCATED AT





REFERENCES

ERS ARE LOCATED

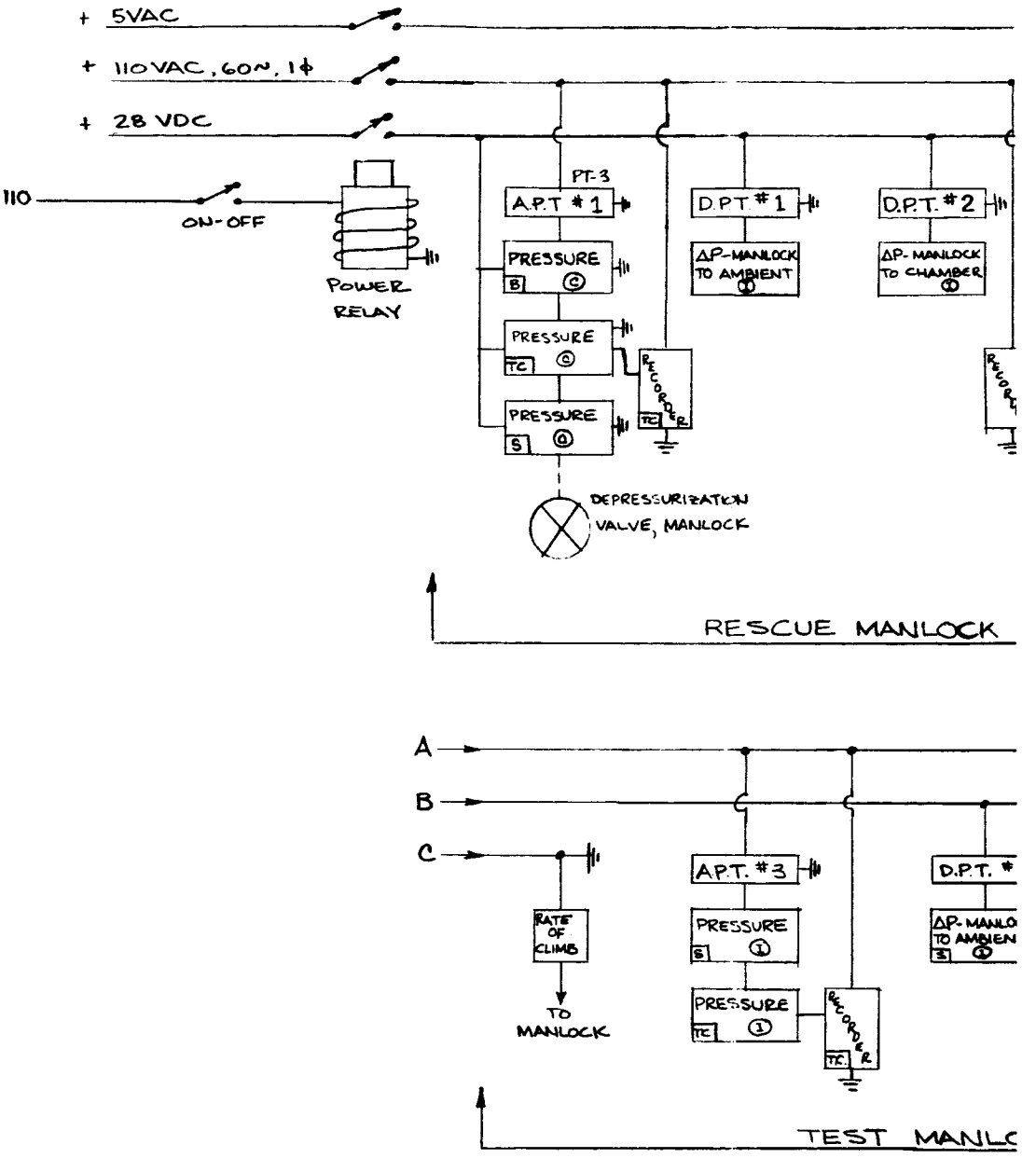
1. DRAWINGS: 201R803
   201R804

ND RECORDERS ARE
ONSOLES

2. SCHEMATIC: FIG. 1-B
   APPENDIX B

FIGURE 5-E - SCHEMATIC
RECS INSTRUMENTATION

SYSTEM CONTROL CONSOLE

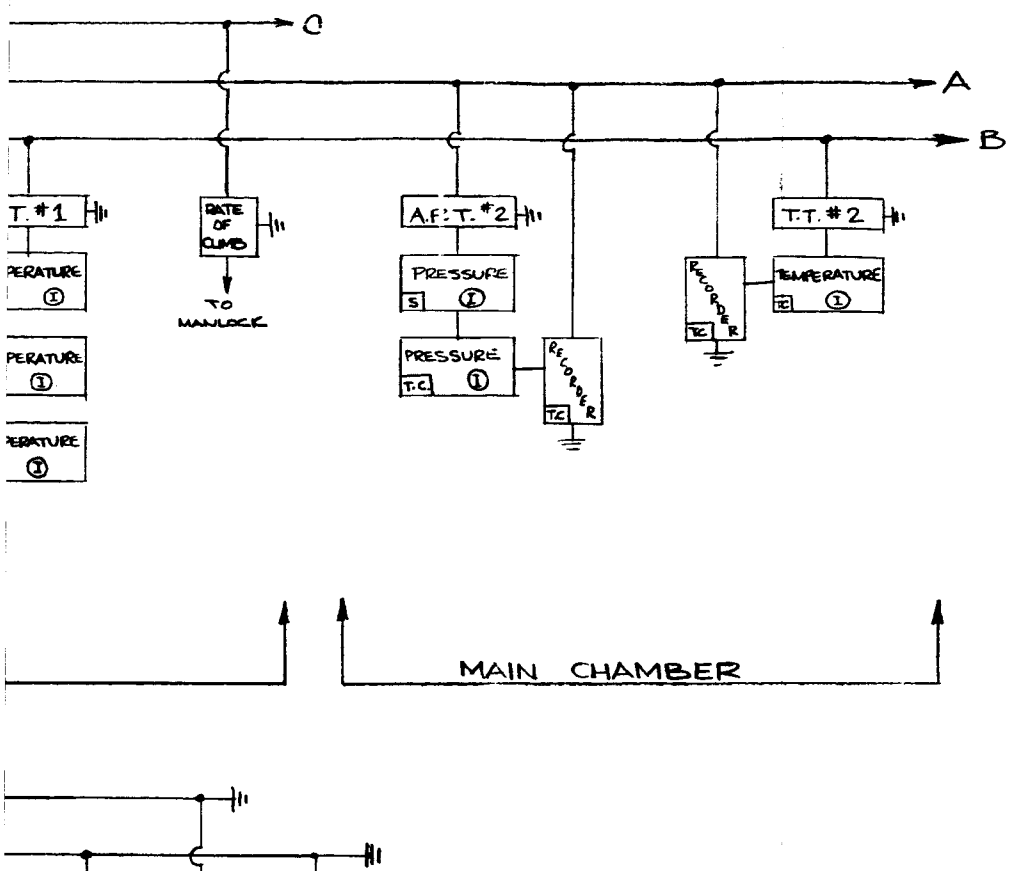


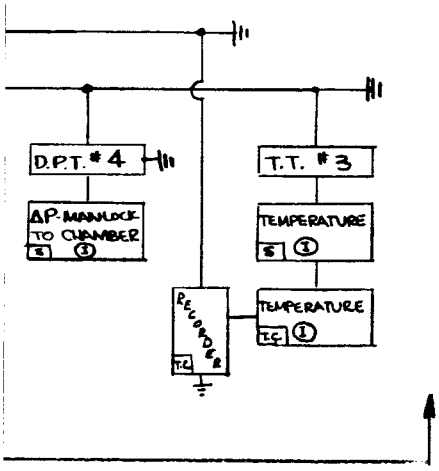
NOTES

1. LEGEND AND SYMBOLS ARE AS IN FIGURE 4-E
2. ALL TRANSDUCERS ARE LOCATED AT RESPECTIVE CHAMBER
3. METERS AND RECORDERS ARE LOCATED AT CONSOLES DENOTED BY THE FOLLOWING:
   a) B - BIOMEDICAL, RESCUE
   b) TC - TEST CONDUCTOR
   c) S - SYSTEM CONTROL

REFERE

1. DRAU
2. SCHE





5

- 201R804
  201R803
  253E554

5 - FIG 1-B (APPENDIX B)

FIGURE 6-E SCHEMATIC CHAMBER AND MANLOCK INSTRUMENTATION
SYSTEM CONTROL CONSOLE

2

CONTROL CONSOLE, DESIGN SPECIFICATION

1. SCOPE

This specification establishes the design requirements for a series of Control Consoles to be used in conjunction with the NASA/Langley 55 foot space environment simulation chamber. The following requirements define a system capable of providing continuous monitoring and control of parameters necessary for sustaining suited test subjects and unsuited rescue personnel in a vacuum environment and adequate controls to alleviate an emergency condition should it arise. An abridged medical monitoring console for use in the treatment and recovery room is also subject to this specification.

2. APPLICABLE DOCUMENTS

2.1 Government and Military Documents

The following documents in effect on the date of issuance of this specification form a part of this specification to the extent defined herein.

Specifications

MIL-Q-5923	Quality Control Requirements, General
MIL-E-4158	Electronic Equipment, ground general requirements for
MIL-W-16878	Wire, Electrical

Standards

MIL-STD-130B	Identification and Marking of Equipment

2.2 Other Publications

The following documents in effect on the date of issuance of this specification form a part of this specification to the extent defined herein.

Drawings

253E553	Control Console, Bio-Med, Test Subject (G.E.)
201R803	Control Console, Bio-Med, Rescue Subjects #1 and #2 (G.E.)
201R804	Control Console, System (G.E.)
253E554	Control Console, Test Conductors (G.E.)
702914	Panel, Airlock (NASA-LRC)
253E555	Medical Monitoring Console, Recovery and Treatment Room (G.E.)

Specifications

SVS7434	Bio-Instrumentation Specification

3. REQUIREMENTS

3.1 Description of Control Consoles

The control consoles are defined as equipment necessary to:

a) Enable monitoring and recording of selected physiological and behavioral characteristics necessary for cognizance as to the well-being of both test and rescue personnel while in the chamber and manlocks. (Dwgs. 253E553 and #201R803)

b) Control and record both manlock environments independently (Dwg. #201R804).

c) Control and monitor the environmental control systems (ECS) for both the suited test subjects and the rescue manlock. (Dwg. #201R804).

d) Monitor and record selected parameters describing the environment of manlocks and chamber (Dwg. #201R804 and 253E554).

e) Initiate the emergency repressurization sequence (253E554).

f) Display status, via a light panel, of selected system parameters (253E554).

g) Monitor biomedical parameters of a suited subject in the treatment and recovery areas.

To accomplish the above, six separate consoles will be needed and can be defined as follows:

a) Test Subject Console - two required

b) Rescue Personnel Console - one required

c) Systems Control Console - one required

d) Test Conductor Console - one required

e) Medical Monitoring Console - one required

The control consoles are to be located external to the chamber and manlocks and are to include all instrumentation and electrical components necessary to provide the above-mentioned control and display features. Connections to and from consoles, i.e., to sensors, transducers, recorders, etc., are to be considered part of the control consoles.

3.2 Design and Construction

3.2.1 Console Construction

The consoles shall be modularly constructed and include the following features:

a) Desk top area where not already provided by NASA-LRC

b) Control panels as per configurations delineated in referenced drawings.

c) Front access via doors or removable panels for servicing.

d) Standard 19 inch relay racks for panel mounting.

e) Sufficient channels or ducts with proper electrical separation for routing of control and power wiring as well as low level signal and instrumentation wiring.

3.2.2 Instrumentation

3.2.2.1 Test Subject Console

The test subject console shall contain the following instrumentation as shown on drawing 253E553.

3.2.2.1.1 Biomedical

a) Console shall include facilities for recording all biomedical parameters as delineated in referenced Specification SVS 7434.

3.2.2.1.2 ECS

The following items are considered vital to the test subject's viability and shall be displayed in conjunction with the biomedical parameters.

a) Flow Rate - The flow rate out of ECS shall be measured. The readout shall have a 0 to 20 CFM full scale with ±2% accuracy and be equipped with adjustable "high" and "low" visible warning limits.

b) Outlet Temperature - ECS outlet temperature shall be displayed and have a full scale range of +30° to +120°F ±2% and be equipped with adjustable "high" and "low" visible warning limits.

c) Outlet Pressure - ECS outlet pressure shall be displayed and have a full scale range of 0 to 20 PSIA, ±2% and be equipped with adjustable "high" and "low" visible warning limits.

d) Oxygen Partial Pressure - The oxygen partial pressure shall be displayed and have a full scale range of 0 - 1200 mm Hg., ±2%. A suppressed scale range of 0 to 300 mm Hg., ±2% with adjustable "high" and "low" visible warning limits shall also be provided.

e) Carbon Dioxide Partial Pressure - The carbon dioxide partial pressure shall be displayed and have a full scale range of 0 to 20 mm Hg., ±2% with adjustable "high" and "low" visible warning limits.

f) Suit Coolant Inlet Temperature - The suit coolant inlet temperature shall be displayed and have a full scale range of 30^{o} to 120^{o}F $\pm$2% with adjustable "high" and "low" visible warning limits.

g) Suit Coolant Outlet Temperature - The suit coolant outlet temperature shall be displayed and have a full scale range of 30^{o} to 120^{o}F $\pm$2%.

h) Emergency Oxygen - A warning light shall be provided to indicate emergency oxygen make-up. A redundant light shall also be provided.

3.2.2.2 Rescue Personnel Console

The rescue personnel console shall contain the following instrumentation as shown on drawing #201R803.

3.2.2.2.1 Biomedical - See appendix F.

a) Console should include facilities for recording all biomedical parameters delineated in reference appendix.

3.2.2.2.2 RECS

The following items are considered vital to the rescue personnel environment and shall be monitored in conjunction with the biomedical parameters.

a) Flow Rate - The flow rate out of the RECS shall be displayed and have a full scale range of 0 to 140 CFM, $\pm$2% with adjustable "high" and "low" visible warning limits.

b) Outlet Temperature - RECS outlet temperature shall be displayed and have a full scale range of 30^{o} to 120^{o}F $\pm$2% with adjustable "high" and "low" visible warning limits.

c) Outlet Pressure - RECS outlet pressure shall be displayed and have a full scale range of 0 to 20 PSIA $\pm$2% with adjustable "high" and "low" visible warning limits.

d) Oxygen Partial Pressure - The oxygen partial pressure shall be displayed and have a full scale range of 0 - 800 mm Hg, $\pm$2%. A suppressed scale range of 0 to 200 mm Hg, $\pm$2% with adjustable "high" and "low" visible warning limits shall also be provided.

e) Carbon Dioxide Partial Pressure - The carbon dioxide partial pressure shall be displayed and have a full scale range of 0 to 20 mm Hg., ±2% with adjustable "high" and "low" visible warning limits.

3.2.2.2.3 Rescue Manlock

a) Pressure - The pressure in the rescue manlock shall be displayed and have a full scale range of 0 to 800 mm Hg., ±2% with adjustable "high" and "low" warning limits.

b) Temperature - The temperature in the rescue manlock shall be displayed and have a full scale range of 0 to 200°F, ±2% with adjustable "high" and "low" warning limits.

3.2.2.3 Systems Control Console

The systems control console shall contain the following instrumentation as shown on drawing #201R804.

3.2.2.3.1 ECS - Test Subject #1

a) Flow Rate - The flow rate out of the ECS shall be displayed and have a full scale range of 0 to 20 CFM, ±2% with adjustable "high" and "low" visible warning limits. A bi-directional momentary switch shall be provided to increase or decrease the flow rate as required.

b) Outlet Pressure - The ECS outlet pressure shall be displayed and have a full scale range of 0 to 20 PSIA, ±2% with adjustable "high" and "low" visible warning limits. A flow-correct device shall be provided with a dial to select the proper total pressure at which flow meter should indicate. A relay shall be provided to actuate solenoid valve in ECS when pressure decreases below low limit on control meter.

c) Outlet Temperature - The ECS outlet temperature shall be displayed and have a full scale range of 30° to 120°F, ±2% with adjustable "high" and "low" visible warning limits. A potentiometer shall be provided for control of temperature.

d) Heat Exchanger Outlet Temperature - The heat exchanger outlet temperature shall be displayed and have a full scale range of 30° to 120°F, ±2%.

e) Oxygen Partial Pressure - The oxygen partial pressure shall be displayed and have a full scale range of 0 - 1200 mm Hg., ±2% A suppressed scale range of 0 - 300 mm Hg., ±2% with adjustable "high" and "low" visible warning limits shall also be provided. The control meter shall have an output signal converter, in conjunction with two relays such that required control of the ECS oxygen make-up solenoid valve can be effected.

f) Carbon Dioxide Partial Pressure - The carbon dioxide partial pressure shall be displayed and have a full scale range of 0 to 20 mm Hg., ±2% with adjustable "high" and "low" visible warning limits.

g) Suit Coolant Inlet Temperature - The suit coolant inlet temperature shall be displayed and have a full scale range of 30° to 120°F, ±2% with adjustable "high" and "low" visible warning limits. A potentiometer shall be provided to afford temperature control.

h) Suit Coolant Outlet Temperature - The suit coolant outlet temperature shall be displayed and have a full scale range of 30° to 120°F, ±2%.

j) Suit Coolant Pump Current - An ammeter shall be provided to display suit coolant pump current and shall have a full scale range of 0 to 3 amps AC, ±2%. A pump on - off switch shall be provided with light to signify pump - on.

k) Blower Current - The ECS blower current shall be displayed and have a full scale range of 0 to 15 amps AC, ±2%.

l) Blower Inlet Pressure - The blower inlet pressure shall be displayed and have a full scale range of 0 to 20 PSIA, ±2% with adjustable "high" and "low" visible warning limits. A relay shall be provided to actuate solenoid valve in ECS when pressure exceeds "high" limit of control meter.

m) Heat Exchanger Coolant Pump Current - An ammeter shall be provided to display heat exchanger coolant pump current and shall have a full scale range of 0 to 3 amp AC, ±2%.

n) Coolant Tank Temperature - Coolant tank temperature shall be displayed and have a full scale range of 30° to 120°F, ±2%.

p) Switches and Indicating Lights

1) A system on - off switch shall be provided which will initiate power to ECS components.

2) Guarded switches shall be provided to effect purging of both the ECS and the suit.

3) Lights signifying system, vacuum pump, and refrigeration unit "on" shall be provided.

q) Tank Pressures - The oxygen, nitrogen, and emergency oxygen tank pressures shall be displayed and have a full scale range of 0 to 2000 PSIG, ±2%.

r) Recorders - Recorders shall be provided to continuously record the following:

1) ECS outlet pressure

2) ECS outlet temperature

3) Oxygen partial pressure

4) Carbon dioxide partial pressure

3.2.2.3.2 ECS - Test Subject #2 - Same as 3.2.2.3.1

3.2.2.3.3 ECS - Rescue Manlock (RECS)

a) Flow Rate - The flow rate out of the RECS shall be displayed and have a full scale range of 0 to 140 CFM, ±2% with adjustable "high" and "low" visible warning limits. A bi-directional momentary switch shall be provided to increase or decrease the flow rate as required.

b) Outlet Pressure - The RECS outlet pressure shall be displayed and have a full scale range of 0 to 20 PSIA, ±2% with adjustable "high" and "low" visible warning limits. A flow correct device shall be provided with a dial to select the proper total pressure at which flow meter should indicate.

c) Outlet Temperature - The RECS outlet temperature shall be displayed and have a full scale range of 30° to 120°F, ±2% with adjustable "high" and "low" visible warning limits. A potentiometer shall be provided for control of temperature.

d) Heat Exchanger Outlet Temperature - The heat exchanger outlet temperature shall be displayed and have a full scale range of 30° to 120°F, ±2%.

e) Oxygen Partial Pressure - The oxygen partial pressure shall be displayed and have a full scale range of 0 - 800 mm Hg., ±2%. A suppressed scale range of 0 - 200 mm Hg., ±2% with adjustable "high" and "low" visible warning limits shall also be provided. The control meter shall have an output signal converter, in conjunction with two relays such that required control of the ECS oxygen make-up solenoid can be effected.

f) Carbon Dioxide Partial Pressure - The carbon dioxide partial pressure shall be displayed and have a full scale range of 0 to 20 mm Hg., ±2% with adjustable "high" and "low" visible warning limits.

g) Blower Current - The RECS blower current shall be displayed and have a full scale range of 0 to 3 amps AC, ±2%.

h) Blower Inlet Pressure - The blower inlet pressure shall be displayed and have a full scale range of 0 to 20 PSIA, ±2%.

j) Heat Exchanger Coolant Pump Current - An ammeter shall be provided to display heat exchanger coolant pump current and shall have a full scale range of 0 to 3 amps AC, ±2%.

k) Coolant Tank Temperature - Coolant tank temperature shall be displayed and have a full scale range of 30° to 120°F, ±2%.

l) Switches and Indicating Lights

1) A system on - off switch shall be provided which will initiate power to RECS components.

2) A guarded, momentary on - off switch shall be provided to effect purging of the RECS. In conjunction with this a switch shall be provided for selection of oxygen or nitrogen as purge gas.

3) Lights signifying system and refrigeration unit "on" shall be provided.

m) Tank Pressure - The oxygen and nitrogen tank pressures shall be displayed and have a full scale range of 0 to 2000 PSIG, ±2%.

n) Recorders - Recorders shall be provided to continuously record the following:

1) RECS outlet pressure

2) RECS outlet temperature

3) Oxygen partial pressure

4) Carbon Dioxide partial pressure

3.2.2.3.4 Rescue Manlock

a) Pressure - The pressure in the rescue manlock shall be displayed and have a full scale range of 0 to 800 mm Hg., ±2% with adjustable "high" and "low" warning limits. A switch to open or close a valve for depressurization of manlock will be actuated by the high and low settings of the control meter.

b) Temperature - The temperature in the rescue manlock shall be displayed and have a full scale range of 0 to 200°F, ±2%.

c) Differential Pressure - Manlock to Ambient - The pressure difference between the rescue manlock and ambient shall be displayed and have a full scale range of 0 - 0.2 PSID, ±2%. Sufficient overload protection shall be provided for meter to withstand differential pressures in excess of scale range.

d) Differential Pressure - Manlock to 55' Chamber - The pressure difference between the rescue manlock and the 55' chamber shall be displayed and have a full scale range of 0 - 0.2 PSID, ±2%. Sufficient

overload protection shall be provided for meter to withstand differential pressures in excess of scale range.

e) Normal Repressurization and Depressurization - A guarded three position switch shall be provided to effect manlock pressure increase or decrease as required.

f) Rate of Climb - A rate of climb meter having a scale range of 0 - 6000 ft/min for both increasing and decreasing pressure rates of change shall be provided.

3.2.2.3.5 Test Manlock

a) Pressure - The pressure in the test manlock shall be displayed and have a full scale range of 0 - 800 mm Hg., ±2%.

b) Temperature - The temperature in the test manlock shall be displayed and have a full scale range of 0 to 200°F, ±2%.

c) Differential Pressure - Manlock to Ambient - The pressure difference between the test manlock and ambient shall be displayed and have a full scale range of 0 to 0.2 PSID, ±2%. Sufficient overload protection shall be provided for meter to withstand differential pressures in excess of scale range.

d) Differential Pressure - Manlock to 55' Chamber - The pressure difference between the test manlock and the 55'chamber shall be displayed and have a full scale range of 0 to 0.2 PSID, ±2%. Sufficient overload protection shall be provided for meter to withstand differential pressures in excess of scale range.

e) Controls - A graphic panel as per Langley Research Center drawing No. 702914 including necessary controls for pressure control of test manlock shall be provided. The panel shall also include a rate of climb

meter having a scale range of 0 - 6000 ft/min for both increasing and decreasing pressure rates.

3.2.2.3.6 Chamber

a) Pressure - The pressure in the 55' chamber shall be displayed and have a full scale range of 0 - 800 mm Hg., ±2%.

b) Temperature - The temperature in the 55' chamber shall be displayed via a multi-point (12 channel) temperature indicator having a full scale range of 0° to +200°F, ±2%. A selector switch shall be provided on instrument for selection of channel to be monitored.

3.2.2.4 Test Conductor Console - The test conductor console shall contain the following instrumentation as shown on drawing 253E554.

3.2.2.4.1 Chamber

a) Pressure - The pressure in the chamber shall be displayed with a full scale range of 0 to 800 mm Hg., ±2%.

b) Temperature - The temperature in the chamber shall be displayed with a full scale range of 0 to 200°F, ±2%.

c) Recorders - Recorders shall be provided to continuously record the pressure and temperature in the chamber. The recorders shall have dual speed capabilities (12 in/hr, 12 in/min) in order to accurately record emergency repressurization data. The recorders shall also be equipped with an event marker such that the commencement of emergency repressurization can be denoted.

3.2.2.4.2 Test Manlock - The parameters to be displayed and recorders are identical to those in preceding section (3.2.2.4.1)

3.2.2.4.3 Rescue Manlock - The parameters to be displayed and recorded are identical to those in preceding section (3.2.2.4.2).

3.2.2.4.4 Status Panel - The status panel shall include a graphic panel displaying the on - off status of the 55' vacuum chamber pumps and blowers as shown on drawing 253E554. It shall also contain the status of the various ECS and RECS components requiring an electrical input, i.e., pumps, blowers, etc.

3.2.2.4.5 Emergency Repressurization - Three switches shall be provided to initiate, via relays all emergency repressurization devices for each manlock separately or the chamber and manlocks.

3.2.2.5 A medical monitoring console, as shown on drawing no. 253E555, shall be provided for the Treatment and Recovery Room. The console shall display all biomedical parameters per Test Subject Console Dwg. 253E553 except for suit parameters. This console shall adhere to this specification and be equipped with an umbilical-compatible electrical connector per MS-3110E-18-325.

4.0 GENERAL

The components for the control consoles shall meet the specifications dictated by the standard catalog date of the component manufacturer.

4.1 Acceptance Testing - The control console system shall be subjected to the following test.

4.1.1 Examination of Product - Each control console and associated hardware shall be examined to determine compliance with the applicable drawings and all requirements of this specification.

4.1.2 Continuity Test - A continuity test shall be performed on each line emanating from the control consoles. Each connection between specific meter and its associated transducer and/or recorder shall be checked by applying a voltage of less than 5V at console end and evidencing continuity at other end.

APPENDIX F

BIOMEDICAL FACILITY EQUIPMENT CONSIDERATIONS

This facility will include areas for 1) preparation of subjects who will enter the chamber, 2) a treatment room for subjects who have had to be removed from the chamber for medical reasons, and 3) a recovery room for those subjects who have received treatment after removal, but do not require hospitalization.

For subjects in any of the aforementioned three areas, there will be available, for use by the attending physician, a console, duplicating the Biomedical Monitors containing ECG, heart rate, temperature, and respiration rate instrumentation and readout. (See spec SVS 7435 & Dwg. #253E555).

The preparation area will be used for pretest physical examination and instrumentation of the subjects. The treatment room is suitable for emergency first aid measures, but is not intended for the handling of major medical procedures. The recovery room may be used for individuals who received minor medical treatment, require a brief rest after a test or are awaiting transportation to a hospital.

Additional items may be desired, but have been left to the discretion of the physician in charge. The list is comprised of those items considered basic for a facility of this type.

PROCUREMENT LIST

BIOMEDICAL FACILITY EQUIPMENT

		Quantity
1.	EENT Treatment and Diagnostic Unit AMS Cat # 021-001	1
2.	Two Crank Hospital Bed AMS Cat. 2941GP	2
3.	Hospital Mattress AMS Cat # 8524	2
4.	Goose Neck Floor Lamp AMS Cat # 800	3
5.	Portable Resuscitator (Emerson) AMS Cat # 494160	1
6.	Instrument Cabinet AMS Cat # 415	1
7.	EENT Chair AMS Cat # 2682-85	1
8.	Ambulance Stretcher AMS Cat # 4002	1
9.	Cardiac Defibrillator (AC) AMS Cat # 522-H	1
10.	Waste Receiver GPP & Son Cat # 905420	1
11.	Wheel Stretcher GPP & Son Cat # 621190	1
12.	Surgeon's Examining Stool GPP & Son Cat # A214720	2
13.	3 Panel Aluminum Folding Screen GPP & Son Cat # 110440	1

AMS = American Medical Supply Co. - Phila.

GPP & Son = Geo. P. Pilling & Son - Phila.

APPENDIX G

DENITROGENIZATION EQUIPMENT DESIGN CONSIDERATIONS

INTRODUCTION

A layout of a denitrogenization area depicting the equipment and its arrangement is shown in drawing 233R302. This equipment is sized to handle the denitrifying requirements of five (5) men (3 suited and 2 unsuited), as well facilitate checkout of already mounted biomedical sensors.

SYSTEM DESCRIPTION

At three (3) denitrifying stations there is available a) an aviator's breathing mask connected with flexible hose to a pressurized oxygen manifold, b) an umbilical connected to a ventilating air source, a liquid coolant outlet and an electrical harness interface for remote biomedical sensor output display and calibration by means of the control console readouts. These stations are for the use of the suited subjects. The two (2) remaining stations are for the denitrifying of the rescue personnel and contain only electrical umbilical and oxygen connections.

The oxygen manifold is fed from a bank of oxygen bottles thru a pressure limiting regulator located on the bottles. Manifold pressure is to be set at 150 PSI $\pm$ 10% to feed a wall-mounted demand regulator containing a quick-disconnect coupling. This coupling mates with a mating disconnect on the end of a 5 foot flexible hose and aviator's breathing mask assembly at each denitrifying station. The breathing mask's retaining straps will have to be modified to facilitate disconnecting in the frontal area so as to be able to completely remove it while wearing a helmet with an open face seal.

The electrical connector located on the wall at each station is the mating-half of the umbilical-contained connector (appendix C), and connects to a conduit which passes thru the facility wall to a 32-place set of terminal blocks. The connection of a cable to these terminals and subsequent routing to the control console will be the responsibility of NASA/LRC. The connection to the suited subjects will be accomplished by a 10' long umbilical (appendix C, part #113C8797G3) that terminates at the subject end with the standard connector assembly used throughout the facility (appendix C, part #201R801). The rescue personnel will require a simple harness (32 wires, 22 ga stranded - approximately 10' long) with the appropriate sensor interface, which will be the responsibility of NASA/LRC.

The three (3) suited subject stations will as previously described, have available a standard umbilical section which will also have provisions for delivering ventilating air and liquid coolant to the suited subjects. The ventilating air is fed to the umbilical through a manifold pressurized by a centrifugal blower located outside of the denitrifying area. The blower with on-off controls in the room induces this air from within the denitrifying area through a filter, and the air then exhausts from the suit primarily through the open face seal back into the room. Throttling valves at each station can be used to adjust the air quantity to each suit and an adjustable relief valve on the supply manifold is intended to minimized air delivery variations as the number of subjects are varied. Heat removal from the ventilating air is to be accomplished by the room's air conditioning system.

The liquid coolant supply and return lines are intended for use with some suits (existing and planned) requiring same. There is a flow adjusting valve at each station and the pump (a part of the ECS equipment-appendix A) can be turned on and off from within the room.

DESIGN ANALYSIS & EQUIPMENT SELECTION

OXYGEN SUPPLY

An average at-rest value for young, adult, male breathing volume requirements is 500 cc's breath and 12 breaths/minute. Total average inhalation then is : $500 \frac{cc}{breath} \times 12 \frac{breaths}{min} \times 5 \text{ men} \times \frac{ft^3}{28316 \text{ cc}} = \frac{1.06 \text{ ft}^3}{min}$

mass flow of O_2 = $.083 \frac{lb}{ft^3} \times 1.06 \frac{ft^3}{min} = 0.088 \frac{lb}{min}$ or 5.28 lb/hr.

Since manifold pressure of the O_2 line is to be regulated at 150 PSI, the O_2 supply bottle is effectively empty at this pressure. Large bottles are available that contain 213 SCF at 2200 PSIG (18 lbs. O_2) and because of the 150PSI manifold pressure:

$$\frac{2215 - 165}{2215} \times 18 \text{ lbs.} = 16.7 \frac{\text{lbs } O_2}{\text{bottle}} \text{ is available}$$

so for each bottle connected to the manifold:

$$16.7 \text{ lbs.} \times \frac{\text{hour}}{5.28 \text{ lb}} = 3.16 \frac{\text{hours}}{\text{bottle}}$$

Considering the variations of breathing volumes in individuals, it is desirable to connect multiple bottles to the manifold. Four bottles are shown so as to give at least 3 changes of maximum crew size. This quantity however, can be changed at the discretion of Langley-LRC without affecting the system design per se.

LIQUID COOLANT SUPPLY

The ECS coolant pump will deliver 4 lb/min of coolant to the denitrifying facility. Since this rate of coolant flow is sufficient for one (1) suited subject in the chamber, (2000 BTU/HR) it is deemed adequate for the subjects in the denitrifying room at their minimal level of activity.

The line sizing remains consistent with the umbilical coolant line size (3/8") so line drops should be commensurate unless the room location is significantly remote from the ECS location. The pump is adequately sized to deliver the 4 lb/min at an even greater head than that for the umbilical, if necessary (see appendix A).

The coolant lines between this pre-breathing area and the ECS is a facility installation (NASA/LRC) and it is pointed out that it could be insulated with Johns-Mansville aerotube insulation (1/2" thick) or equivalent to remain consistent with this equipment design.

The anticipated temperature rise in the coolant flow when the subject's heat loads are in the order of 500 BTU/HR each will be:

$$3 \times 500 \frac{BTU}{HR.} \times \frac{lb^{o}F}{.81\ BTU} \times \frac{min}{4\ lb} \times \frac{hr}{60\ min} = 7.7^{o}F$$

VENTILATING AIR

When air is used to cool the subject in the pre-breathing room it is seen that 11.5 CFM/min will have a temperature rise of:

$$500 \frac{BTU}{HR.} \times \frac{min}{11.5\ ft^{3}} \times \frac{lb^{o}F}{1\ BTU} \times \frac{ft^{3}}{.075\ lb.} \times \frac{hr}{60\ min} = 9.7^{o}F$$

From this is follows that if the room is kept in the vicinity of 70°F. The exhaust air from the suit should not get over 80°F.

To obtain this air flow (3 x 11.5 = 34.5 CFM) a Rotron blower (Model # LRPU, type A6-120005) was selected on the basis of the following calculated pressure drops.

Total pipes, fittings & valves	2.75 in. H_2O
filter	1.00 in. H_2O
suit (Gemini)	19.90 in. H_2O
umbilical	4.15 in. H_2O
disconnects	4.00 in. H_2O
	31.80 in. H_2O

The delivery curve of the fan selected specifies it can delivery 34.5 CFM against a head of 33 in. H_2O. Therefore, some spare capacity is available for any increase in subject activity or change in suit or system pressure drop characteristics.

ALTERNATE SYSTEM CONSIDERATIONS

In view of the many methods available in accomplishing denitrogenization of subjects about to enter a vacuum chamber at reduced pressure levels, there should be some discussion of these alternate schemes. The arrangement depicted here requires the use of an O_2 mask and an open face seal for the walk from the pre-breathing room to the manlock. This scheme also requires a purge of the suit by the ECS when the subject first enters the manlock, while keeping the face seal open.

Another scheme could be used which would denitrify the subject by just blowing O_2 into the suit with the face mask closed, while exhausting thru the suit exhaust port to the ambient. This could be continued with a portable bottle for the walk to the manlock. Of course, O_2 consumption is extensive and the fire hazard is greater.

A combination of the two aforementioned schemes could be used by cooling the suit with ambient air, however while walking to the manlock, the face seal could be closed and O_2 exhausting thru the suit exhaust port could be used for breathing and ventilating on the way. The mobility of the bottle required may become a problem when considering the amount of O_2 needed.

When evaluating these schemes, the maximum hardware design and minimum operating cost required occurs when utilizing the design presented. It is felt then that when the trade-offs are considered by NASA/LRC the scheme selected if not this one, will require a minimum of study and design.

DENITROGENIZATION EQUIPMENT SPECIFICATION

1.0 SCOPE

This specification establishes the minimum performance and physical requirements for the design, manufacture and testing of the equipment necessary for the denitrogenization and checkout of test subjects prior to their entering the NASA/Langley vacuum cylinder for full pressure suit tests.

2.0 APPLICABLE DOCUMENTS

2.1 Specifications

The following specifications and ammendments in effect on the effect on the date of issuance of this specification are part of this specification:

SVS7433	Umbilical Subsystem
SVS7431	Suit Environmental Control System
MSFC-Spec. - 164	Oxygen Equipment
QCS-100-0	Quality Control Systems
MIL-W-8160	Wiring Guided Missile, Installation of
OT-364	Trichlorethylene, Technical
MIL-W-16878	Wire, Electrical
MIL-O-27210B (ASG)	Oxygen, Aviators Breathing Type 1 Gas

2.2 Standards

The following standards in effect on the date of issuance of this specification are part of this specification.

MS-355-86	Metals, Definition of Dissimilar
MIL-STD-130B	Identification and Marking of U.S. Military Property

2.3 Drawings

The following drawings in effect on the date of issuance of this specification are part of this specification.

Umbilical Coupler Assembly	113C8797
Denitrogenization System	253R802

3.0 REQUIREMENTS

3.1 Description

The equipment shall be used for keeping the subjects pressure suits ventilated and cooled while they are seated and undergoing denitrogenization. It shall also be used to electrically interface with biomedical and suit instrumentation for checkout of these sensors prior to the subject's entry into the environmental chamber. There shall be five denitrogenization stations (hereafter referred to as DS) each equipped with an aviator's type breathing mask that is coupled to a central source of aviator's breathing oxygen. Three of the five stations shall have umbilical assemblies which mate with the umbilical connectors on the subjects pressure suits. These umbilicals shall connect the biomedical and suit instrumentation to the chamber readout panel. The umbilicals will also connect the ventilating air system to each pressure suit. The ventilating air shall be circulated by a blower located outside the DS room. After passing through the suits, the air shall discharge into the room and return to the blower in a return duct. In addition the umbilicals shall connect liquid coolant system to the pressure suits if required. This coolant shall be recirculated through a pump and heat exchanger which is not included in this specification. (See SVS-7431) Each station shall also have a portable demand oxygen assembly with an attached regulator for use in transit to the manlock.

3.2 Acceptance

The equipment and system furnished under this specification shall be tested to satisfy the acceptance requirements specified herein.

3.3 Deviations

Approval of NASA/LRC shall be required for deviations to this specification.

3.4 Materials

Materials will conform to SVS7431, paragraphs 3.2.1, 3.2.2, 3.2.3, 3.2.4 and 3.2.6.

3.5 Design and Construction

3.5.1 General Arrangement

The equipment shall be arranged as shown on drawing no. 253R802.

3.5.2 Instrumentation Wiring

All instrumentation wiring shall be 22 gage stranded, shielded wire. Twisted pairs will be used wherever possible. Insulation shall be compatible with Paragraph 3.4.1.3.2 of this specification.

3.5.2.1 Umbilical Disconnect

Instrumentation wiring inside the DS room at each station shall terminate in a panel mounted electrical connector which is the mating half of the electrical connector built into the umbilical (SVS-7433). The wires shall penetrate the DS room wall directly behind the connector panel and terminate on terminal blocks located in a covered wire way located on the outside of the DS room wall.

3.5.3 Seats

An individual seat will be provided for each station. Each seat will be covered with a washable plastic material compatible with paragraph 3.4.1.3.2 of this specification and formed so as to preclude tearing of the subjects pressure suits.

3.5.4 Liquid Coolant

Liquid coolant shall be provided to the 3 stations assigned to suited subjects for use when liquid-coolant suits are being used.

3.5.4.1 Umbilical Disconnect

The supply and return liquid coolant lines at each of three stations shall terminate in MS-33660-G fittings. The umbilical coolant lines shall bit over these fittings and be fastened to the copper tubing with hose clamps.

3.5.4.2 Liquid Coolant Lines

The copper tubing and other parts of the liquid coolant system shall be structurally capable of operating at 125 PSI minimum working pressure. Soldered joints shall be used wherever possible. All copper liquid coolant tubing shall be covered with 1/2" of fiberglas insulation and shall be fastened to the exterior walls of the DS room at minimum 4 foot intervals.

3.5.4.3 Flow

The liquid coolant system shall be capable of providing a minimum 1.33 lb/min of 55°F coolant (40% by weight of Ethylene Glycol solution) to each of three of the DS stations for periods of up to 8 hours. Flow regulation will be provided by a suitable manually operated throttling valve at each location.

3.5.4.4 Pump

The liquid coolant system pump which is located outside the DS room and which is not a part of this specification shall be controlled by an on-off switch located in the DS room which controls a motor starting switch on the motor.

3.5.5 Ventilating Air System

Ventilating air shall be provided to the same three stations mentioned in 3.5.4 of this specification.

3.5.5.1 Umbilical Disconnect

The air supply line at each of the three stations shall terminate in a wall mounted fitting which can be attached to the oxygen inlet line of the umbilical at that station using a hose clamp.

3.5.5.2 Flow

The ventilating air system shall be capable of providing a minimum of 11.5 CFM of air at 70°F and 29 in. H_2C to each of three stations, just upstream of the umbilicals. Flow regulation will be provided by a 3/4" manually operated angle throttling valve at each location.

3.5.5.3 Air Lines

The air shall be delivered to the DS room in 2" copper tubing. Solder joints will be used @ all joints, and the pipes will be fastened to the exterior walls of the DS room at minimum 4 foot intervals.

3.5.5.4 Blower

The air blower shall provide a minimum of 34.5 CFM of 70°F air at a minimum of 32" H_2O discharge pressure. It shall operate from 220 V 60 cycle, 3 phase AC power and be located outside the DS room. It shall be controlled by an on - off switch located in the DS room which controls a motor starting switch on the motor.

3.5.5.5 Air Filter

A 20" x 16" x 2" replaceable furnace type filter will be mounted in the DS room to return the ventilating air to the blower after it passes through the pressure suits and DS room.

3.5.6 Oxygen System

Aviator's breathing oxygen per MIL-O-27210B(ASG) shall be provided to all five stations.

3.5.6.1 Supply

The oxygen shall be supplied from four high pressure (2400 PSIG) medical oxygen cylinders of 213 SCF minimum each, volume which shall be located in the DS room and connected to a supply manifold which goes to each station. The output of each cylinder shall terminate in a female CGA No. 540 fitting. (Compressed Gas Association).

3.5.6.2 Oxygen Lines

The tubing and fittings shall be type 304SST structurally capable of withstanding 2500 PSIG proof pressure. Welded joints shall be used wherever possible. The tubing shall be fastened to the interior DS room walls at minimum 6 foot intervals.

3.5.6.3 Flow

The system shall be capable of providing 25 .088#/min. of oxygen for a minimum of 10 hours.

3.5.6.3.1 Regulators

Each station shall have a wall mounted demand oxygen regulator capable of demand delivering .0176 #/min. from a 50 to 1800 PSIG source. Each regulator shall discharge into a flexible hose through a quick disconnect type female connector. (See Para. 3.5.6.4 this spec.).

Each oxygen cylinder shall have a line mounted regulator with a male input CGA number 540 fitting (Compressed Gas Association). These shall each be capable of regulating up to .088 #/min. of oxygen at 150 PSIG $\pm$10% discharge pressure from a 2500 PSIG source. They shall have high and low pressure side pressure gages and a low pressure side adjustable relief valve nominally set at 200 PSIG $\pm$10%.

3.5.6.4 Aviator's Breathing Masks

Each station will have an aviator's type breathing mask complete with a non-compensated combination (to preclude the necessity of pressure breathing) valve and 5 feet of flexible hose which terminates in a quick disconnect type male connector which mates to the female connector mentioned in Paragraph 3.5.6.3.1 of this specification.

3.5.6.5 Portable Oxygen System

Each station will have a portable 400 PSIG oxygen cylinder with an attached demand regulator. The regulator discharge fitting shall be a quick disconnect female type with mates with the male fitting on the breathing mask hose. The cylinder will be capable of providing .0176 #/min for minimum of 15 minutes.

4.0 ACCEPTANCE REQUIREMENTS

4.1 Inspection

4.1.1 Oxygen System

All components used in the oxygen system shall be visually examined for evidence of corrosion products, metal chips, burrs, feather edges, grease, paint or other contamination which constitutes a functional hazard to the system. Such contamination shall be cause for rejection.

4.1.2 Instrument Calibration

All pressure gages and regulators in the system shall be checked for calibration prior to installation in the system. Vendor certification of instrument calibration, based on independent laboratory tests, shall also be acceptable as proof of the accuracy of these items. In either case, the calibrations shall be traceable to National Bureau of Standards references.

4.2 Testing

4.2.1 Instrumentation Wiring

All instrumentation wiring will be continuity checked with a maximum of 12 volts applied between pins on the panel mounted connectors (Paragraph 3.5.2.1) and terminal blocks outside of the DS room.

4.2.2 Liquid Coolant

This system shall be subjected to 125 PSIG proof pressure before installation of the insulation and umbilicals. There shall be no visible evidence of water leakage at this pressure.

4.2.2.1 Purging

After soldering and before installation of the umbilicals the water lines shall be purged of foreign material with 4 lb/min. of water flow for one hour.

4.2.2.2 Flow

The liquid coolant system shall be tested for flow capacity using the system flowmeter and pump (neither is part of this specification) in conjunction with three pressure suit - umbilical restrictions. With the equivalent restrictions attached to the three sets of water system outlets in the DS room and the pump operating at full capacity, the flowmeter shall indicate no less than 4 lb/min.

4.2.3 Oxygen System

This system shall be subjected to 2500 PSI proof pressure before installation of the regulators, using clean dry N_2.

4.2.3.1 Leak Test

The oxygen system shall, when pressurized to 150 PSIG, exhibit a pressure decay of no more than 6 PSIG in 24 hours with the supply regulators closed.

4.2.3.2 Cleanliness

All oxygen lines and equipment shall be cleaned and tested utilizing applicable procedures outlined for oxygen equipment in MSFC-SPEC-164 prior to installation in the DS room. After welding all joints and prior to installing regulators the lines will be cleaned and dried according to Paragraph 3.5.1.6 of MSFC-SPEC-164.

4.2.4 Ventilating Air System

This system shall be tested for flow by attaching a calibrated flowmeter and static pressure gage to the air outlets before installation of the umbilical. The instruments shall indicate a minimum of 11.5 CFM at 29"H_2O pressure.

4.2.4.1 Purging

After soldering and before installation of the umbilicals the ventilating air lines will be purged for fifteen minutes with water and dried for one hour with air supplied by the system blower.

APPENDIX H

List of Drawings:

1.	ECS Assembly	-	201R805
2.	Reheater Ass'y.	-	113C8798
3.	Venturi Ass'y.	-	113C8799
4.	CO_2 Canister Ass'y.	-	101D1340
5.	Heat Exchanger Ass'y.	-	113C8788
6.	Condensate Tank Ass'y.	-	113C8795
7.	Umbilical Ass'y.	-	113C8797
8.	Umbilical Cover and Restraint	-	253E551
9.	Umbilical Coupler Ass'y.	-	201R801
10.	Umbilical Test Fixture	-	101D1344
11.	Biomedical Sensor Locations and Umbilicals Harness & Coupler	-	201R806
12.	Test Conductor Console	-	253E554
13.	Bio-Med/ECS Test Subject Console	-	253E553
14.	Bio-Med/ECS Rescue Subject's Console	-	201R803
15.	Systems Control Console	-	201R804
16.	Medical Monitor Console - Treatment & Recovery Room	-	253E555
17.	Denitrogenization Equipment	-	253R802
18.	Umbilical Installation - Conceptual	-	253E552
19.	Door Notch Concept	-	SK56152-852

LIST OF DRAWINGS (Cont'd)

20.	Heat Exchanger Housing	-	113C8787
21.	Heat Exchanger Reducer Ass'y.	-	113C8786
22.	Heat Exchanger Coil	-	151B6001
23.	Heat Exchanger Baffle	-	151B6002
24.	Heat Exchanger Fitting	-	151B6003
25.	CO_2 Canister Cover Ass'y.	-	101D1339
26.	CO_2 Canister Housing	-	113C8789
27.	CO_2 Canister Cover	-	151B6005
28.	Reheater Ass'y. Housing	-	113C8796
29.	Reheater Ass'y. End Cap	-	101D1343
30.	Reheater Ass'y. Baffle	-	151B6008
31.	Reheater Ass'y. Heating Coil	-	151B6009
32.	Venturi Ass'y. Adapter Flange	-	113C8825
33.	CO_2 Canister Bottom Plate	-	113C8790

APPENDIX J

WORK STATEMENT

This exhibit from RFP L-5669 is included herein for reference only.

1. INTRODUCTION

(a) Experimental programs are being undertaken at the Langley Research Center to define and solve pertinent operational problems associated with man's performance of necessary tasks in space and on the moon and planets. One such program now being planned will utilize the Langley 55-Foot Vacuum Cylinder on a part-time basis where men, equipped with pressurized suits (serviced with umbilical systems and/or back packs), and in some cases supported by harness or inclined planes to simulate gravitational effects, will be assigned to perform tasks representative of those required for servicing and repair of spacecraft in orbit and on extraterrestrial surfaces, for explorations on these surfaces utilizing self and vehicle locomotion, and for establishment of shelters and bases needed for production and research.

(b) The purpose of this contract is to design and/or specify all equipment and services needed to supplement existing hardware and systems of the Langley 55-Foot Vacuum Cylinder to assure that it is fully man-rated. Standards to be followed shall in general conform to those given in AIA Report No. ARTC-41: "Recommended Safety Practices for Manned Space Chambers" dated July, 1964, with certain exceptions and additions which will be noted in subsequent sections of this specification. Neither the design and

specifications of pressure suits and research models nor systems for simulation of gravitational fields is intended to be a part of this contract; however, the fact that man will be required to perform tasks utilizing such equipment and devices should be considered in the specifications of pressurization systems, protective equipment and emergency or recovery systems. The existing building hardware and systems are described in subsequent sections. That portion of the building reserved for suiting, prebreathing and recovery has not been constructed and can be modified within reason if the study so indicates.

(c) Emphasis shall be placed on achieving safe, reliable operation with the least amount of costly embellishments. The physiological and behavioral characteristics of man himself will be monitored only to a degree sufficient to adequately assure his well-being. Control consoles and monitor systems shall be designed or selected to minimize the number and duties of attendant personnel for sustained test periods. Trained technicians will be used for chamber operation. A Flight surgeon will be in constant attendance in the early phase of chamber operation but may be placed on standby attendance if subsequent evaluation of chamber safety operation indicates insignificant exposure to risk.

2. THE CONTRACTOR SHALL PERFORM THE FOLLOWING TASKS:

(a) Provide the systems design for all man-rating, emergency and recovery systems necessary for manned operations of the LRC 55-Foot Vacuum Cylinder within the aforementioned guidelines for personnel before, during and after exposure to vacuum environment.

(b) Establish requirements for modification and/or additions to the existing facility and its equipment necessary to provide the features defined in paragraph 2(a). These requirements together with a preliminary estimate of costs to meet the requirements shall be submitted to the Government for review, and then subsequently modified as required.

(c) Upon approval by the Government of the requirements of paragraph 2(b) as finally revised, prepare detailed specifications, drawings and cost estimates for procurement by contract of all services and equipment necessary to implement the requirements of paragraph 2(b) except for modifications to the building structure which will be the responsibility of the Government.

3. EXISTING FACILITIES

(a) Laboratory - The Dynamics Research Laboratory consists of a number of items of research equipment together with support equipment, work areas, control centers and offices. It is designed for carrying out research on spacecraft structure, equipment and materials under various environmental conditions. The equipment includes a large backstop, a 55-foot diameter vacuum cylinder with whirl table, a 60-foot diameter free-body dynamics sphere, a 7-foot environmental chamber, a 1000-pound shock tester, an analog computer, and shakers ranging in size up to 30,000-pound output. A plot plan of the laboratory is shown in Figure I-1.

(b) Building - A first floor plan view of that portion of the building associated with the 55-foot vacuum cylinder is shown on figure VDB 1-18-65. A basement below Room 110 houses roughing pumps. A second story above Room 107 houses air conditioning equipment and above Rooms 103, 104 and 118 houses offices and rest rooms. The floor of Room 122

which houses the airlock is elevated two feet above the remainder of the building. There is no second floor over this room but an enclosure for diffusion pumps shown in Figure VDB 12-14-64, VDB 12-24-64, VDB 1-4-65 and slated for construction during 1965 will extend over this area. Figure VDB 1-18-65 also shows the general location and preliminary first floor arrangement of an addition now being planned for the ready room, suiting, prebreathing and recovery areas.

(c) Cylinder - The plan view of the general arrangement and location of the cylinder and associated equipment is given on Figure III-1. The section view, Figure III-2, shows the whirl table in the cylinder, the large service door, and elevations of removable floor, fixed floor, and overall dimensions. The whirl table can be removed and a hemispherical dome installed to seal its operating mechanism.

(1) The vessel is of carbon steel construction with internally reinforced cylindrical side walls and a hemispherical dome. There are fourteen 10-inch diameter laminated glass viewing and photography ports spaced about the cylindrical side walls as shown on Figure III-3.

(2) The removable open grating steel floor shown on Figure III-4 is supported by removable steel beams and removable steel columns. This floor is designed to carry a maximum load of 250 pounds per square foot with the steel columns in place. With the columns removed (to allow use of the whirl table) the permissable uniform load is 100 pounds per square foot. A twenty-foot-square service door provides access to the vessel. A five-tone motorized trolley hoist is located at the top of the cylindrical shell. The beam for this hoist which can be manually rotated in 22-1/2 degree increments is removable to accommodate large test specimens. The service door, trolley hoist, and beam are shown on Figure III-2. The interior of the cylinder is coated with U.S. Stoneware K-63 white vacuum paint.

(3) Details of lighting and utilities available within the vessel and the location of instrumentation and utility feed-thru ports are given in Figure III-5. With all lights energized and approximate lighting intensity at Elevation 15.2 (floor grating is 100-foot candles).

(4) The cylinder evacatuion system consists of two Roots-Connersville blowers, four Stokes Microvac pumps, and 4 CVC diffusion pumps. The blowers and Microvac pumps are also used to evacuate the 60-foot Free Body Dynamics Sphere. Piping is arranged to split the system for holding both chambers at reduced pressure. The graphic control panel for this pumping equipment detailed in drawings LD-702717 and LD-703578 is located in Room 107. An abridged panel located in Airlock Room 122 and detailed in drawing LD-702914 permits control of that portion of the pumping system required to evacuate the cylinder airlock. Normal repressurization of the cylinder to atmospheric pressure requires 100 minutes. Emergency repressurization can be effected by inbleeding atmospheric air through two 42-inch diameter pneumatically-actuated valves. A timer in the valve control circuit is now set to permit repressurization to 285 torr in 8 seconds. An override to atmospheric pressure can be made in an additional 37 seconds. Controls for the emergency inbleed valves are located on the Airlock Control panel. At present there are no diffusers on the cylinder interior to reduce the blast of inrushing air.

(d) Airlock - The airlock arrangement is shown in Figure III-6. It is equipped with five 10-inch diameter laminated glass observation ports and three 8-inch feed-thrus. Each door is latched with retractable, linked dogs actuated by a hand-wheel which requires 4 seconds to go from fully closed to open position. Two overhead fluorescent lights provide illumination.

Level of illumination in the airlock is 200 foot candles and in Room 122 is 70 foot candles.

(1) The airlock is provided with a pressure altitude control system incorporating means for evacuating by use of a roughing pump and for repressurizing by atmospheric inbleed. Ascent rates can be controlled from 10 torr per minute to 816 torr per minute. Descent rates can be controlled from 10 torr per minute to 478 torr per minute. An emergency inbleed system which utilizes a timer-controlled valve can repressurize the airlock from 10^{-1} torr to 285 torr in 10 seconds. An externally controlled equalizer between the airlock and cylinder permits alternate method of equalizing airlock pressure. The interior of the airlock is provided with manual valved to control airlock pressure with respect to either the cylinder or to the outside atmosphere.

(e) Control Panel - The arrangement of the control panel located in the airlock room is shown on drawing LD-702914. The controls and gages provided to date have been arranged to permit easy incorporation into a graphic display. The control system for the airlock and for the emergency repressurization of the cylinder is diagrammed in drawing VDB 2-4-65.

4. DESIGN CONSTRAINTS

Guidelines - The following guidelines apply for this particular study:

(a) The chamber will be manned at vacuum levels as low as 10^{-4} torr.

(b) At no time will man carry out experiments without wearing a full pressure suit, and therefore will not be exposed directly to any noxious gases within the chamber.

(c) No experiments will be carried out which will generate explosions or explosive gases.

(d) No cryogenic systems will be used inside the chamber. No high temperature sources need to be considered.

(e) Support systems will be compatible for both back-pack and suit systems.

(f) At any one time no more than two men will be required to perform experiments within the cylinder exclusive of standby personnel within the airlock.

(g) The entire area of Room 122 will be available for use as a control center for manned experiments.

(h) Waste gases from the suits normally should not exhaust directly into the cylinder but may be allowed for certain suit designs.

(i) AIA Report No. ARTC-41 "Recommended Safety Practices for Manned Space Chambers" dated July 1964, shall be used as a general guide in establishing requirements but departure from the provisions of the report will be allowed at the discretion of the contractor. Specific variations from ARTC-41 include:

1.	Section 2.1	Delete requirement for materials which maintain ductility at cryogenic temperatures.
2.	Section 2.1.4	Delete
3.	Section 2.1.5	Delete
4.	Section 2.1.8	Delete
5.	Section 2.1.14	Emergency power will be provided by gasoline-powered generator floating on the line.

6.	Section 2.1.15	Delete
7.	Section 2.1.16	Delete
8.	Section 2.2	Shall be the responsibility of the government.

(j) Bio-Med Transducers and Console - Bio-med transducer, telemetry or direct-line links, signal conditioning equipment and display and control consoles shall be selected or designed consistent with measurements and conditions specified in AIA Report No. ARTC-41 as heretofore modified. Attention should be directed toward arriving at a display-monitoring-recording system which will minimize the number of personnel required to carry out safe, efficient test operations. ARTC-41 Section 3.4.3 and 3.4.4 shall be modified accordingly.

(k) Auxiliary Areas - AIA Report No. ARTC-41 shall be used as a guide in specifying equipment for the Suiting Room, Prebreathing Room, Ready Room and Recovery Room.

(l) Operating Procedure - While general considerations of operating procedure will be required in arriving at design specifications for equipment and services, no formal submittal of detailed operating procedure is required.

5. PERFORMANCE

(a) Upon award of contract, the Contractor shall visit the site and obtain detailed information on existing facilities and equipment necessary to carry out his study.

(b) The Contract shall submit ten (10) copies of informal progress letter report at the end of the first month, after date of contract. This letter shall be in a narrative form, including a quantitative description of overall progress and shall be submitted within five (5) calendar days after the first day of the month following the reporting period.

(c) The Contractor shall submit ten (10) copies of a design report at the end of the second month, after date of contract. This report shall contain the design of all systems, and a description and preliminary cost estimate of all services and equipment required.

(d) Ten calendar days after receipt of the design report by the Contracting Officer the Contractor shall visit the Langley Research Center to review this report with representatives of the Government and to make any necessary revisions.

(e) The Contractor shall then prepare and submit at the end of the fifth (5) month after date of contract, ten (10) copies of detailed specifications, drawings, and cost estimates for all required services and equipment. The reviewed copy of these specifications and drawings will be returned to the Contractor within fourteen calendar days after their receipt by the Government.

(f) The Contractor shall then deliver ten (10) copies and a reproducible copy of the final specifications and drawings within 14 calendar days after receipt of the reviewed copy of the final specifications and drawings.

APPENDIX K

MANLOCK REQUIREMENTS SPECIFICATION

GENERAL

Entry into the vacuum cylinder by personnel is primarily for the purpose of performing specifically designated tasks ranging from observation to repair and entry into test vehicles. Such entry requires passage through an intermediate chamber or lock in order to bridge the pressure differential between normal atmospheric pressure and the low chamber test pressures.

Definition

The personnel entry lock will consist of two chambers, arranged to give parallel access with an interconnecting passage. In addition, each chamber will have provisions for communications, atmosphere control, limited access penetrations, instrumentation, plumbing systems and valves necessary to control the pressure, such that each can operate independently of the other.

Purpose

The purpose of the test personnel entry lock is to provide for the walk-in capability for pressure suited personnel entering or leaving the chamber. The lock utilized by rescue personnel must provide for the sustenance of unsuited personnel at some intermediate pressure, say that equivalent to 25000'.

Size

The minimum size manlock should each be able to comfortably and safely accommodate a 2 man crew, plus supplies, tools, etc. Sufficient clear floor space should be provided to allow a stretcher borne man to be

accommodated without interference during opening of any of the manlock doors.

Pressure Control System

The lock pressure control system shall consist of the necessary equipment distribution ducting, controls, and valves to permit decompression and/or pressurization of either lock chamber in conjunction with or independently of the simulator chamber.

Communications

Voice communications shall be maintained between the lock occupants and all crews operating in the cylinder as well as control room and bio-medical monitoring personnel. Visual monitoring and communication shall be provided by viewing ports in the lock walls and closed circuit TV.

Instrumentation and Controls

Instrumentation and controls shall consist of the necessary sensors, wiring and interlocks, alarms, and readout devices to integrate the complete operational capabilities of the lock with the operation of the cylinder.

Lighting

The lock shall be artifically illuminated to permit adequate and safe performance of all anticipated tasks. Provisions shall be made for emergency lighting in the event a general power failure occurs.

Personnel Entry Lock Structure

Construction

Construction shall be in accordance with the requirements of "Code for Unfired Pressure Vessels" of the American Society of Mechanical

Engineers, 1959 Edition, Section VIII.

Door

The inner door shall be capable of being opened manually from either side by one man in a pressurized suit. Safety interlocks should be provided to prevent door opening when cylinder pressure exceeds internal lock chamber pressure by a significant amount, or vice versa.

The passageway should have a minimum width of 40 inches and a minimum height of 78 inches.

All sharp corners and edges should be protected and/or covered to prevent suit punctures.

Penetrations

Penetrations for the vacuum pumping system should be located on the bottom quadrant of the air lock chambers.

Penetrations for venting the air lock chambers should be in the bottom of the lock.

There should be penetrations for viewing ports so as to view the inside of the personnel entry lock. Viewing ports shall be also provided in the lock to permit viewing of operations in the chamber.

Pumping System

The overall pumping system shall be capable of maintaining operating pressures (i.e. 1 atm. to 1 x 10^{-4} torr) in the test personnel lock with minimum gas loads of 1500 atmospheric cc's per minute of pure oxygen. (Gas load from 2 pressurized suits).

The pumping system shall be capable of evacuating the manlock chambers to a pressure of (1 x 10^{-4} torr) in a period of time commensurate

with safety and task performance requirements. This system should utilize chamber systems where possible.

Venting System for Normal Shut-Down

The venting system should be capable of re-pressurizing the personnel entry locks independently of the cylinder pressure vessel to ambient pressure in a period not to exceed one minute.

The venting system should introduce air into the bottom quadrant of the chamber for re-pressurization purposes.

The noise level in the lock during normal re-pressurization should not exceed 130 decibels for a period of 30 seconds or 120 decibels for a period of 5 minutes or 108 decibels for 15 minutes.

The noise level in the Simulator Building should not exceed 130 decibels for a period of 30 seconds or 120 decibels for a period of 5 minutes or 110 decibels for 15 minutes during re-pressurization of the manlock.

Emergency Re-pressurization System

The lock must have an emergency re-pressurization system.

Rate and Composition

The emergency recompression system for personnel lock must be capable of achieving specific rates and composition. These rates are indicated by Figure 1 or Rapid Repressurization System Requirements Spec.

Allowable Noise Level

The noise level in the man locks shall not exceed 130 decibels for a period of 30 seconds or 120 decibels for a period of 5 minutes during emergency recompression. The noise level in the building shall not exceed 130 decibels for a period of 30 seconds or 120 decibels for a period of 5 minutes or 110 decibels for 15 minutes during repressurization of the locks.

Maximum Allowable Dynamic Pressures

The dynamic pressures on a standing man in the lock must not exceed 9 pounds per square foot horizontally and 15 pounds per square foot in a vertical direction.

Dynamic pressures on the equipment in the lock must be low enough to preclude physical damage or dislodgement.

Maximum Allowable Temperature Levels

The ambient temperature on the exterior of a space suit located in the personnel lock must not exceed a maximum of 300°F for 1 minute or 200°F for 5 minutes during re-pressurization.

Initiation of Emergency Recompression

The lock must be capable of emergency recompression without recompressing the vaccum cylinder.

Initiation of the recompression signal shall be manually initiated from the test conductor console.

Pump Protection

Oil in the manlock pumps (and in the chamber diffusion and rough pumps) must be protected from unduly high-oxygen partial pressure to prevent explosion, fire, or cracking of the hot pump oils.

Consideration should also be given to the problems associated with pumping essentially pure oxygen with the diffusion pumps and their backing pumps during sustained pumping operations.

Lighting

The locks shall be provided with sufficient permanently installed lighting to maintain an illumination level of 5-foot candles at floor level and between 30 and 100 foot candles at a level of 30 inches off the floor. Where work involving discrimination of fine details is involved a combination of at least 30 foot candles of general lighting plus specialized supplementary lighting is recommended. A.S.A. Standard A-11-1942 (or equivalent) prepared by the Illuminating Engineering Society should be consulted for complete information and recommendations. Supplementary lighting of the areas immediately outside the doors shall also be provided.

Emergency provisions shall be included to provide for minimum requirements in the event of general power loss in the chamber or lock facilities. The emergency lighting system shall be automatically activated within 5 seconds after loss of normal electrical power. The emergency system shall provide a minimum of 5 foot-candles illumination in all areas.

Environmental Control System

Rescue Lock

The environmental control system must maintain the rescue personnel (not in suits) at pressures ranging from 1 atmosphere to 3.0 PSIA.

Test Personnel Lock

The test personnel ECS shall be capable of sustaining full pressure suited personnel for 20 PSIA thru the lowest manlock pressure (1×10^{-4} mmHg) via umbilicals.

ECS system design specifications stipulate in detail the requirements for this equipment.

Average physiological requirements (iterated here for convenience) are as follows:

a.	Oxygen required	37 STP liters/hr.	.11 lbs/hr.
b.	CO_2 produced	29 STP liters/hr.	.12 lbs/hr.
c.	Sensible heat	to 700 BTU/hr.	
d.	Water vapor produced	to 0.5 lbs./hr.	
e.	Noxious odors	trace	
f.	Humidity required	10 + 5 mm Hg H_2O vapor	

Instrumentation and Controls

Provisions (hard wire and/or radio) should be available to monitor and transmit all the biomedical instrumentation required by personnel passing through a residing within the locks.

Parameters that require monitoring, and control are specified under ECS/Biomed Control Console Requirements.

APPENDIX L

RAPID REPRESSURIZATION SYSTEM REQUIREMENTS SPEC.

SYSTEM BIOMEDICAL REQUIREMENTS

Tests that are planned within the Langley 55' vacuum cylinder pose the possibility of a sudden loss of protective environment for test participants, an event which makes rescue (i.e., entering the chamber and removing the test personnel) impractical. The alternate to removing a man to a safe environment, is to establish a safe environment in the area of his incapacitation, thus emergency repressurization.

A number of factors must be controlled during an emergency repressurization procedure to circumvent further jeopardizing the life of the test participants. These parameters include: Thermal, pressure, pressure rate of rise, noise level, and dynamic pressures. A review of available data and requirements established for other facilities such as Mark I and II G.E. Space Simulator, the NASA Houston chambers and ARTC-41 has been used as a basis to generate the following biomedical design factors.

THERMAL

The environment temperature on the test frating must not exceed the following limitations during emergency repressurization:

$300^{o}F$ maximum for one minute

$200^{o}F$ maximum for five minutes

PRESSURE

The pressure in the chamber should be brought to a total pressure of 52 mm Hg. (1.0 psia) within 35 seconds, and partial pressure of oxygen pressure of 650 mm Hg. (12.5 psia) when air is used as the repressurizing

medium. The pressure rise rate should not exceed 25 mm Hg per second (0.5 psi per second) to avoid rupture of eardrums. Figure 1-2 illustrates pressure rise rates that are within the constraints stipulated.

NOISE LEVELS

The recompression cycle shall not induce noise levels in excess of 130 db for 30 seconds, or 120 db for five minutes.

DYNAMIC PRESSURE

The recompression cycle should not subject test personnel to dynamic forces in excess of nine pounds per square-foot in a horizontal direction of 15 pounds per square-foot in a vertical direction.

RAPID REPRESSURIZATION TEST RESULTS AND DESIGN CONFIGURATION

A series of repid respressurization tests were run utilizing various sizes of vacuum chambers at GE-MSD Valley Forge under Contract AF 40(600)-1012 as a part of the Mark I Space Environmental Simulator Man Rating Search Study. Results indicate that the above stipulated Biomedical requirements can be satisfied. (Reference: Rapid Repressurization of Space Simulation Chambers. J.H. Jones, et al).

Figure 2-L depicts schematically the recommended repressurization control configuration.

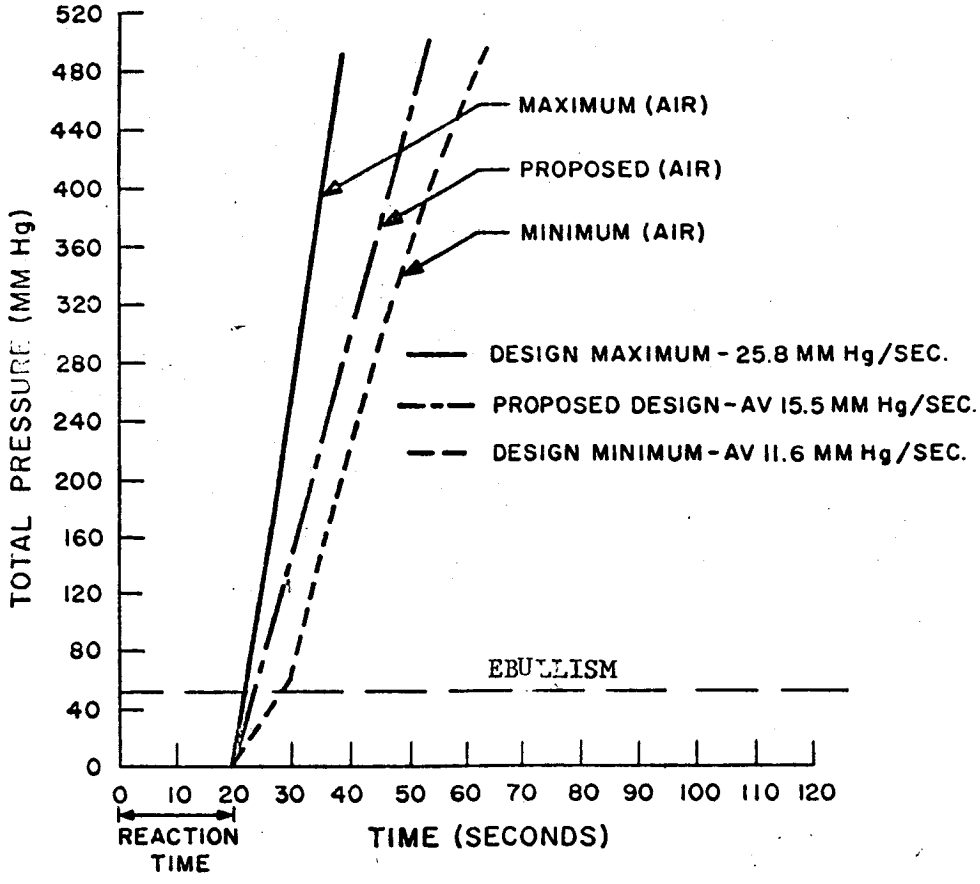


FIGURE 1-L RECOMMENDED EMERGENCY REPRESSURIZATION RATE

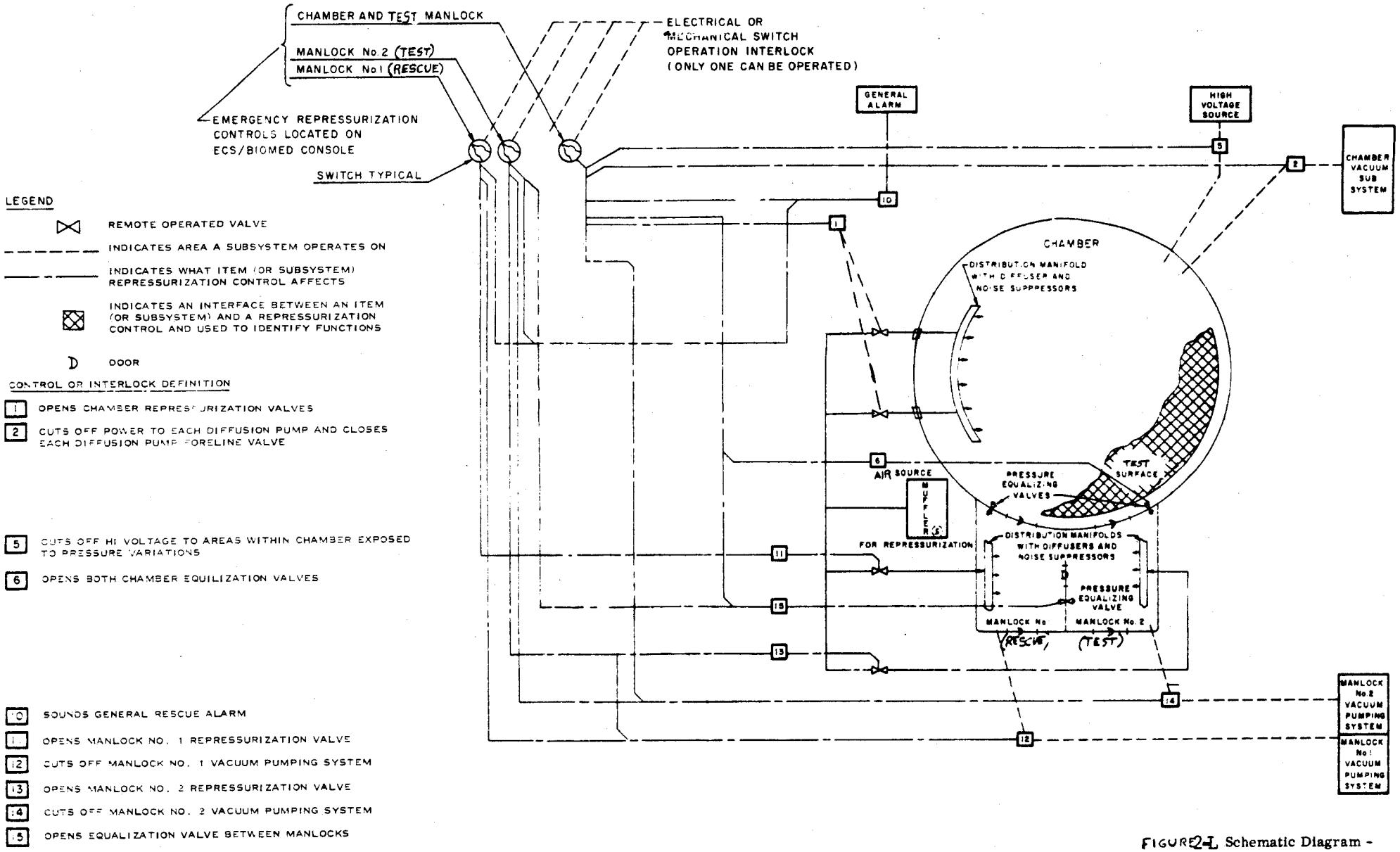


FIGURE 24 Schematic Diagram - Repressurization Controls Function (MODIFIED FROM FIGURE 18 OF REFERENCE 2)

V. REFERENCES

1. Man Rating Research Study on the AEDC Mark I Aerospace Systems Environmental Chamber, R. A. Miller, et al.

2. Study of Man Rating Subsystem Design Criteria for the AEDC Mark I Aerospace Systems Environmental Chamber, R. A. Miller, et al.

3. Research Study of Biomedical Aspects of Aerospace Systems Environmental Chambers AEDC Mark I, Rapid Respressurization of Space Simulation Chambers, J. H. Jones et al.

4. Reliability of Bioinstrumentation Sensors Applicable to Project Apollo Spacecraft by H. Josephs et. al.

5. Heat Transfer and Fluid Flow Design Data Manual Advanced Technology Laboratories, General Electric Company.

6. Handbook of Chemistry and Physics, 37th Edition 1955-1956 Chemical Rubber Publishing Co., Cleveland, Ohio

7. Aero-Space Applied Thermodynamics Manual, SAE, Inc. Committee A-9, February, 1960. Revised Jaunary, 1962.

8. Instruments and Control Systems 1964 Buyer's Guide, Instruments Publishing Co.

9. Miller, R. A., and Withey, D. J., "Emergency Breathing and Suit Pressurization Systems", AMRL-TR-64-60, September 1964.

10. Kays, W. M., London, A.L., "Compact Heat Exchanges," National Press 1955, p. 113, Figure 92.

11. Bioastronautics Data Book, NASA SP-3006, NASA, Wash., D.C., 1964

12. Mechanical Engineer's Handbook, Lionel S. Marks, 4th Ed. McGraw Hill, 1941.

13. Piping Engineering, Tube Turns Research Staff, Louisville, Ky., Aug. 1951.